Contents

GCE AS and A Level Biology/Human Biology Teachers' Guide

NOVEMBER 2013

1 INTRODUCTION

The WJEC AS and A2 Biology specification has been modified and updated, and the Human Biology written, for delivery from September 2008. First examinations at AS level will take place in January and summer 2009 and the first A2 assessments will take place in January and summer 2010. The specifications can be delivered and assessed in centres throughout the UK.

It is the intention of this Guide to be one of the several ways by which the WJEC provides assistance to teachers delivering the specifications sitting alongside: the Specimen Papers; the National Grid for Learning Wales (NGfL Cymru); INSET conferences.

WJEC provides the following as part of its support for all GCE specifications:

- Examiners' reports on each examinations series
- Free access to past question papers via the WJEC secure website
- Easy access to the specification and other key documents on the main website
- Free online exam review programme
- Easy access to both the Subject Officer and to administrative sections

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2 AIMS OF THE TEACHERS' GUIDE

The aim of this Guide is to give additional guidance covering the AS and A level specification content and practical work.

This guide is intended as an adjunct to the specifications and not to supersede them. The documents will therefore need to be read in conjunction with each other.

3 OVERVIEW OF SPECIFICATIONS

SUMMARY OF ASSESSMENT FOR BIOLOGY

This specification is divided into a total of 6 units, 3 AS units and 3 A level units. Weightings noted below are expressed in terms of the full A level qualification. Marks are given as raw and uniform marks (UM).

AS (3 units)

Biology 1	20 % 1 hour 30 min Written Paper 70 marks (120UM)
Unit title Basic Biochemistry and cell organisation Outline of paper structure – Short and longer structured questions, choice of 1 from 2 essays.	
Biology 2	20 % 1 hour 30 min Written Paper 70 marks (120UM)
Unit Title Biodiversity and physiology of Body Systems Outline of paper structure – Short and longer structured questions, choice of 1 from 2 essays.	
Biology 3	10 % Internal assessment 44 marks (60UM)
AS Unit AS Practical assessment Experimental work set in centre, plus, low power plan microscope drawing. Marked by WJEC. This practical work must be carried out between 1 January and 15 May of the year in which it is submitted for assessment. Centres must inform WJEC of the date(s) when practical assessments are to be carried out.	

A LEVEL (the above plus a further 3 units)

Biology 4	20 % 1 hour 45 min Written Paper 80 marks (120UM)
Unit title Metabolism, Microbiology and Homeostasis Outline of paper structure – Short and longer structured questions, choice of 1 from 2 essays. Small % synoptic marks.	
Biology 5	20 % 1 hour 45 min Written Paper 80 marks (120UM)
Unit title Environment, Genetics and Evolution Outline of paper structure – Short and longer structured questions, choice of 1 from 2 essays. Small % synoptic marks.	
Biology 6	10 % Internal assessment 50 marks (60UM)
A level Unit AL Practical assessment Experimental work set in centre, plus, one microscope drawing and calibration. Marked by the WJEC. This practical work must be carried out between 1 January and 15 May of the year in which it is submitted for assessment. Centres must inform WJEC of the date(s) when practical assessments are to be carried out.	

SUMMARY OF ASSESSMENT FOR HUMAN BIOLOGY

This specification is divided into a total of 6 units, 3 AS units and 3 A level units. Weightings noted below are expressed in terms of the full A level qualification. Marks are given as raw and uniform marks (UM).

AS (3 units)

Biology 1 20 % 1hour 30 min Written Paper 70 marks (120UM)
Unit title Basic Biochemistry and organisation Outline of paper structure – Short and longer structured questions, choice 1 from 2 essays.
Human Biology 2 20 % 1hour 30 min Written Paper 70 marks (120UM)
Unit Title Biodiversity and physiology of Body Systems Outline of paper structure – Short and longer structured questions, choice 1 from 2 essays.
Biology 3 10 % Internal assessment 44 marks (60UM)
AS Unit AS Practical assessment Experimental work set in centre, plus, low power plan microscope drawing. Marked by WJEC. This practical work must be carried out between 1 January and 15 May of the year in which it is submitted for assessment. Centres must inform WJEC of the date(s) when practical assessments are to be carried out.

A LEVEL (the above plus a further 3 units)

Human Biology 4 20 % 1 hour 45 min Written Paper 80 marks (120UM)
Unit title Metabolism, Microbiology and Homeostasis Outline of paper structure – Short and longer structured questions, choice 1 from 2 essays. Small % synoptic marks.
Biology 5 20 % 1 hour 45 min Written Paper 80 marks (120UM)
Unit title Environment, Genetics and Evolution Outline of paper structure – Short and longer structured questions, choice 1 from 2 essays. Small % synoptic marks.
Biology 6 10 % Internal assessment 50 marks (60UM)
A level Unit AL Practical assessment Experimental work set in centre, plus, one microscope drawing and calibration. Marked by the WJEC. This practical work must be carried out between 1 January and 15 May of the year in which it is submitted for assessment. Centres must inform WJEC of the date(s) when practical assessments are to be carried out.

All assessment units are available in June. The Biology and Human Biology assessments are timetabled at the same time.

Biology and Human Biology options

One theory unit at AS (BY2/HB2) and one at A2 (BY4/HB4) is a Biology/Human Biology option. One unit at each of AS and A2 (BY1 and BY5) is common to both courses as are the style of practical assessments. However the subject matter used for the practical assessment may differ between Biology and Human Biology.

Candidates' choice of units will determine whether they obtain a qualification in either Biology or Human Biology. A candidate will be awarded a Human Biology qualification if they aggregate marks from HB2 for AS and HB4 for A2. A biology qualification will be awarded if the aggregation comprises only Biology units (BY1-6) or if HB2 is aggregated with all A2 Biology units for an A level qualification.

4 CHANGES FOR TEACHING FROM SEPTEMBER 2008

Summary of overall changes to content:

Unit 1

This unit is relatively unchanged although less depth is expected and a few topics removed.

Unit 2

Radically altered unit to emphasise comparative adaptations in a range of organisms.

Unit 4

Respiration and photosynthesis retained but large parts of the remaining content substituted by content from unit 5 from the previous specification.

Unit 5

Protein synthesis with genetics, retained in this unit, plus environmental issues rather than homeostasis.

Guide to more specific changes

Some content has been moved between units or to Human Biology:

(References to new specification are sub-section e.g. 1.7; to old specification in brackets e.g. (2))

1.4 digestive enzymes to Human Biology 2.2;
1.6 structure of ATP to 4.1;
1.6 replication, protein synthesis and genetic engineering to 5.1 and 5.6;
1.7 meiosis to 5.1;
2.1 includes classification modified from (5);
2.4 includes reproduction from (5);
2.5 includes digestion but that from (4) is now Human Biology 2.2;
4.5 populations from (2);
4.2 reference to long distance running and starvation to Human Biology 4.2;
4.4 pathogens, disease and immunity to Human Biology 2.5, 2.6;
4.6 homeostasis from (5);
4.7 nervous system from (5);
4.2 muscle action from Human Biology (4)
5.7 ecosystems from (2)
5.8 human effects on the environment from (2);

Some content has been deleted:

1.1 Some of the inorganic ions; 1.1 lipids as an energy store;
4.3 limiting factors;
(4) brain structure;
(5) endocrine control in reproduction;
5.3 development of pollen and ovule plus double fertilisation

Some content has a slightly different emphasis:
1.7 Significance of processes of cell division;
4.5c recycling nutrients;
5.2 reproduction;
5.8 sustainability.

Some content is new:
2.1 biodiversity;
2.6 parasites
4.7 speed of nerve conduction;
5.4 Chi squared, basic linkage, oncogenes;
5.6 stem cells, IVF treatment.

Changes to examination papers

Synoptic assessment is no longer confined to the last unit. It may be included in any A2 assessment and questions may be synoptic within a unit or with another unit, including AS. There is no requirement for a set percentage of such questions on a paper and therefore synoptic assessment may vary.

Some questions maybe common to both the Biology and Human Biology papers.

Changes to practical work

The practical examples given in the specification along with the subject content are suggested rather than mandatory, as previously. It is expected that a range of suitable practical work will be undertaken during the course so that practical skills are developed and theoretical concepts are illustrated and investigated. Practical work may be examined on theory papers, usually as application of knowledge.

Practical Assessments will no longer be sent out on an annual basis to be completed in an answer book provided. Centres are free to devise their own practical work. Candidates should submit details of the method used in their report. Writing the report of the investigation in the provided answer booklet is encouraged.

Planning further work is assessed as a suggested extension to the investigation undertaken rather than as a separate investigation but as previously the plan does not have to be carried out.

A statistical test is no longer a requirement but could be included if appropriate to the investigation.

The requirements for microscope work are reduced to one drawing at AS and a drawing, calibration and scale calculation at A2. However, the requirements within each of these assessments are unchanged e.g. the marking criteria for the drawing are as previously as is the microscope calibration.

Teachers are no longer expected to assess each candidate’s practical skill in the laboratory and submit the marks to WJEC.

The work must be completed under supervised conditions and submitted, as previously, for marking by WJEC.

Differences between Biology and Human Biology Units

Unit 2

Biology includes adaptations of a variety of different organisms to different environments.

Human Biology includes human body systems with medical conditions and disorders. Evolution is taken in the context of Humans and pathogens and the immune system are included.

Unit 4

There are no major topic areas which differ between the specifications but there is a difference of emphasis or context.

Biology includes some adaptations such as nerve nets and kidney function in different environments plus some plant biology.

Human Biology includes human contexts with less detail for photosynthesis. Muscle action is included as are a range of medical disorders.

How Science Works

A consideration of How Science works is a requirement carried on from GCSE. It requires candidates to consider the wider issues surrounding the subject including the validity of data and conclusions along with ethical and social issues. Candidates should be encouraged to use an investigative approach and to question and think around data and information as to its source, relevance and use. Suitable examples are given in the specification but others may be used as appropriate.

Further support materials

A range of support materials have been developed and are available via the Educational Resource area on WJEC website. These materials comprise a range of items from interactive presentations and PowerPoint to revision quizzes and could be used by either teachers or candidates. A variety of topics are covered and more will be developed over time.

5 AMPLIFICATION OF UNIT CONTENT

This amplification is intended to provide clarification for teachers about the depth of knowledge required for the interpretation of the WJEC AS and Advanced Level Biology and Human Biology specifications for first examination in 2009. It does not constitute full, detailed teaching notes nor is it a text book. Greater detail is specified in some parts more than others, more importantly where it is thought that greater clarification is needed. It is, therefore, not suitable for candidates.

AS Level

BIOLOGY/ HUMAN BIOLOGY UNIT 1 (BY1)

1.1 BIOLOGICAL COMPOUNDS

1. Candidates should distinguish between the terms: atom, molecule, element, compound, organic, inorganic.
2. The most common elements in living organisms are hydrogen, carbon, oxygen and nitrogen.
3. The role of magnesium, iron, phosphate and calcium in cell metabolism.
4. Water is essential since all reactions of life rely on water and key elements are found in aqueous solution.
5. The importance of water in terms of its polarity, ability to form hydrogen bonds, surface tension, as a solvent, thermal properties, as a metabolite.
6. Candidates should differentiate between monomers and polymers.
7. Small molecules can be combined by condensation reactions and large molecules broken down by hydrolysis.
8. Carbohydrates consist of carbon, hydrogen and oxygen with the general formula $C(H_2O)n$ and are monosaccharides, disaccharides (soluble, sweet) and polysaccharides.
9. Monosaccharides are monomers named according to the number of carbon atoms: triose, pentose, hexose
10. The structural formula may be a straight chain or a ring, as shown by glucose.
11. Disaccharides are formed by joining two hexose units (as shown by sucrose, maltose and lactose).
12. Glucose exists as two isomers α and β glucose, which form different polymers; starch (amylose and amylopectin) and cellulose.
13. Hydrogen bonding is important in maintaining the shape of biological molecules.
14. Starch and glycogen are storage polysaccharides because glucose can be added or removed easily and they have no osmotic effect in cells because they are insoluble.
15. Cellulose and chitin are similar structural polysaccharides with the alternating isomers allowing cross linking between chains, forming microfibrils. In chitin some –OH groups are replaced by amino acids.
16. The elements which make up lipid molecules are carbon, hydrogen and oxygen plus phosphorus as phosphate in phospholipids.

17. The main types of lipids are described as either oils or fats, depending on their melting points. They are immiscible with water but soluble in some organic solvents. Their functions include insulation, energy storage, protection.
18. Candidates should understand the structure of triglycerides and the structural formula for glycerol and general formula for a fatty acid. Unsaturated fatty acids contain double bonds.
19. Lipids are used, rather than carbohydrates, as an energy store in seeds and animals because of a high yield of energy per gram.
20. The products of lipid hydrolysis are fatty acids and glycerol.
21. The components of phospholipids are glycerol, fatty acids and a phosphate group.
22. Glycerol is hydrophilic and fatty acids hydrophobic.
23. A high intake of fat, notably saturated fats, is a contributory factor in heart disease.
24. Candidates should be able to draw the general formula for amino acids and recognise amino (basic) and carboxylic (acidic) groups.
25. Proteins are polymers of amino acids of which there are twenty types which differ by the R group. (Candidates are not expected to recall names of amino acids but can be expected to identify them, given a structural formula and a suitable table showing -R groups).
26. Polymerisation occurs by condensation, to form peptide bonds giving rise to dipeptides and polypeptides. Candidates should be able to complete a diagram showing this, given the structural formula of an amino acid.
27. Proteins show a primary, secondary, tertiary and quaternary structure.
28. Primary is the type, number and sequence of amino acids linked by peptide bonds only.
29. The most common secondary structure is an alpha helix formed by hydrogen bonding between the peptide bonds in the polypeptide chain (no details of beta pleated sheets required).
30. The tertiary structure is the folding of the alpha helix, as shown by globular proteins, to form very specific three-dimensional shapes.
31. Projecting from the helix are -R groups which may interact to form bonds which help to maintain the tertiary structure's three dimensional shape.
32. Candidates should be able to identify disulphide, ionic, hydrogen and hydrophobic bonds between -R groups.
33. The quaternary structure is where two or more polypeptide chains in tertiary form combine to form complexes joined by bonds similar to those in tertiary structure. Only some proteins, such as haemoglobin, exhibit quaternary structure (detailed structure of haemoglobin not required).
34. Proteins can be classified according to function which is determined by structure: globular proteins function as enzymes, antibodies and hormones; fibrous proteins such as keratin and collagen have alpha helices linked into strands.

1.2 CELL STRUCTURE AND ORGANISATION

1. The cytoplasm of eukaryotic cells is organised by membranous structures e.g. Golgi body/apparatus, nuclear envelope, endoplasmic reticulum, lysosomes, mitochondria, chloroplasts, and the membranes of these structures may be referred to as internal cell membranes.
2. Internal cell membranes are important in providing a transport system, separating areas from the rest of the cytoplasm, providing a large surface area for the attachment of enzymes and other reactants, ATP synthesis.
3. Candidates should be able to recognise on a diagram or electron micrograph, and draw on a generalised diagram of a cell, the above organelles and ribosomes, understanding their relative size.
4. Mitochondria consist of an outer and inner double membrane; inter-membrane space; cristae; matrix; DNA and ribosomes. Their function is energy production (ATP).
5. The endoplasmic reticulum(ER) forms an extensive membrane system of flattened sacs, cisternae, continuous with the nuclear membrane and may link to Golgi body. ER may be smooth, without ribosomes and function in lipid and steroid synthesis or rough, with associated ribosomes and function in protein synthesis as a transport system.
6. Ribosomes consist of two subunits, large and small, made of ribosomal RNA and protein. They may be free in the cytoplasm or bound to ER and function in protein synthesis.
7. The Golgi body/apparatus is a series of dynamic, flattened sacs which function in packaging proteins for secretion by the coalescence of vesicles at one end and budding off at the other.
8. Lysosomes are secretory vesicles, from the Golgi body, containing enzymes used in phagocytosis.
9. Centrioles are used in spindle formation during cell division.
10. Chloroplasts consist of a double outer membrane containing stroma with ribosomes, lipid, circular DNA and possibly starch. Through the stroma are parallel flattened sacs, thylakoids, stacked in places as grana, which are the site of photosynthetic pigments. Between the grana the thylakoids form lamellae. Chloroplasts, along with mitochondria are self replicating.
11. Vacuoles are small vesicles in animal cells and are large and surrounded by a tonoplast in plant calls. Plant cell vacuoles function as storage sites whilst animal cell vacuoles may be formed during phagocytosis or act as contractile vacuoles.
12. The nucleus is bounded by a double membrane the nuclear envelope, with pores to allow transport of messenger RNA (mRNA) and nucleotides. It contains chromatin, extended loosely coiled chromosomes of DNA and histone protein, and the nucleolus where ribosomal RNA (rRNA) is produced.
13. Both plant and animal cells possess: plasma/cell surface membrane, membrane bound nucleus, nucleolus, chromatin, mitochondria, rough and smooth ER, ribosomes, Golgi body/apparatus.
14. Only plant cells possess: chloroplasts, cell wall and plasmodesmata, large vacuole and tonoplast.
15. Cells with distinct membranous organelles are eukaryotic those without are prokaryotic.
16. Prokaryotic cells have no membrane bound organelles or structures such as nuclear membrane or ER. DNA is circular and lies free in the cytoplasm and ribosomes are smaller than those in eukaryotes.

17. The prokaryotic cell wall is not made of cellulose; the site of respiration is infoldings of the cell membrane, the mesosomes. A protective outer layer, the capsule, may be present, as well as small circular structures of DNA, the plasmids.
18. Viruses consist of DNA or RNA, not both, enclosed in a protein coat.
19. In multicellular organisms cells are specialised according to the functions they perform leading to division of labour.
20. An aggregation of similar cells carrying out the same function is a tissue. Epithelia (cuboidal, ciliated), muscle (striated, smooth) and connective tissue (collagen) should be studied in relation to their functions.
21. An organ is an aggregation of several tissues to carry out a particular function for the whole organism.

1.3 CELL MEMBRANES AND TRANSPORT

1. All cells are surrounded by a membrane which may be called the cell surface membrane or the plasma membrane.
2. The cell membrane appears under the electron microscope as a double line.
3. The usual distance across the cell membrane under the electron microscope is 7-8nm.
4. The principal biochemical constituents of the cell membrane are protein and phospholipid.
5. The phospholipid molecules are arranged as a bilayer with hydrophilic heads and hydrophobic tails.
6. Some proteins lie on the surface of the bilayer and some are partly embedded, whilst others extend completely across it.
7. This model is referred to as the 'fluid mosaic' model because the components are free to move with respect to each other.
8. Candidates should be able to draw a simple diagram to illustrate the fluid mosaic model including the labels: phospholipid bilayer, proteins, hydrophilic pores/channels (in some proteins), glycoproteins.
9. The major functions of the cell membrane include taking up nutrients and other requirements; secreting chemicals; cell recognition.
10. The cell surface membrane is selectively permeable to water and some solutes.
11. Candidates should be able to interpret the results of an investigation into factors, heat and organic solvents, affecting the permeability of a cell membrane.
12. Lipid-soluble substances can move through the cell membrane more easily than water-soluble substances, which use temporary protein channels.
13. Candidates should be able to define the term 'diffusion'. It is the movement of molecules or ions from a region of high concentration to one of low concentration.
14. The rate of diffusion across the membrane depends on: the concentration gradient, temperature, size of the molecule, lipid solubility.
15. Candidates should be able to define the term 'osmosis'. It is a particular form of diffusion in which water molecules move down a water potential gradient through a selectively permeable membrane.
16. Water potential is the potential for water to move out of a solution by osmosis. It has the symbol ψ (psi). Pure water has the highest water potential, given the value 0. All solutions have a lower potential than water because they have a lower proportion of water molecules, therefore ψ_s always has a negative value.
17. In a plant cell the water potential is the sum of two factors: the solute potential (ψ_s) which is the effect of solutes lowering the water potential of the cell sap (negative value) and ψ_p which is the opposite pressure provided by the cell wall and is usually positive ($\psi_{cell} = \psi_s + \psi_p$).
18. Candidates should be able to use a given equation and interpret data.
19. When a cell loses water it shrinks; the cytoplasm of a plant cell will draw away from the cell wall and the cell is described as being plasmolysed.
20. A cell will gain water if placed in an hypotonic solution; an animal cell will burst but a plant cell will continue to take in water until prevented by the opposing wall pressure when the cell is described as being fully turgid.
21. Facilitated diffusion allows rapid exchange due to substances being helped across the membrane by special carriers. ATP is not needed.

22. Phagocytosis is where a large particle may enter the cell, become enclosed by a membrane to form a vesicle and be transported through the cytoplasm.
23. Candidates should be able to draw a diagram to illustrate phagocytosis.
24. Secretion or exocytosis refers to substances leaving the cell after being transported through the cytoplasm in a vesicle.
25. The cell membrane is continually having portions removed or added to it through phagocytosis and secretion,
26. Pinocytosis is the entry of liquid by the same mechanism as phagocytosis.
27. Active transport requires energy from respiration and takes place against a concentration gradient so allowing a solute to be accumulated within a cell.
28. Active transport will not take place in the presence of a respiratory inhibitor such as cyanide.
29. A solute may be taken across a cell membrane by a special carrier molecule.

1.4 ENZYMES

1. The general characteristics of enzymes are due to their biochemical nature as globular proteins, showing specificity, requiring certain conditions and with a mode of action lowering the activation energy of a reaction.
2. The substrate binds to part of the protein called the active site.
3. Candidates should understand the action of enzymes explained in relation to enzyme structure - lock and key hypothesis; the theory of induced fit, whereby the specific substrate for the enzyme alters the shape of the active site on binding as illustrated by lysozyme (structural details not required).
4. Enzymes are proteins made inside living cells but may act inside the cell (intracellular) or outside (extracellular) such as the digestive enzymes of the alimentary canal.
5. The rate of an enzyme catalysed reaction increases with increasing temperature due to increased frequency of collisions as shown by a graph.
6. The rate of an enzyme catalysed reaction will vary with changes in pH as shown by a graph.
7. The rate of an enzyme catalysed reaction will vary with changes in enzyme concentration as shown by a graph.
8. The rate of an enzyme catalysed reaction will vary with changes in substrate concentration as shown by a graph.
9. Candidates should be aware of the need for buffers in enzyme experiments and the requirement for adequate controls.
10. Environmental conditions such as temperature and pH change the three-dimensional structure of enzyme molecules. Bonds are broken and hence the configuration of the active site is altered.
11. High temperatures and extreme changes in pH cause permanent change in protein structure, causing denaturation.
12. Small changes in pH cause small reversible changes in enzyme structure, causing inactivation.
13. Inhibition is when enzyme action is slowed down or stopped by another substance.
14. Enzyme inhibition may be competitive whereby an inhibitor, which is structurally similar to the substrate, associates with the enzyme active site. If the substrate concentration is increased so will the rate of reaction.
15. Non competitive inhibition involves an inhibitor combining away from the active site often altering the enzyme shape as illustrated by potassium cyanide. The rate of reaction is unaffected by substrate concentration.

1.5 MEDICAL AND INDUSTRIAL APPLICATIONS OF ENZYMES.

1. Biosensors work because enzymes are specific so they select one type of molecule from a mixture.
2. When a mixture is passed over the enzyme a reaction occurs. The energy released is proportional to the concentration of the substrate and is converted into electrical impulses. Consequently an accurate digital display of concentration is produced e.g. glucose oxidase electrode detects glucose in blood.
3. An enzyme can detect the presence of its substrate even in very low concentrations.
4. The enzyme is immobilised so its structure is stabilised in an inert support e.g. on alginate beads or gel membrane.
5. Industrially an immobilised enzyme can be recovered for re-use. Therefore, a small amount of enzyme may be used to carry out a large-scale reaction.

1.6 NUCLEIC ACIDS

1. The components of a nucleotide are pentose sugar, phosphate plus organic base which contains nitrogen.
2. Nucleotide bases are purines or pyrimidines, linked by condensation reactions to form polymers, RNA and DNA, which can be represented in symbolic form.
3. DNA consists of two chains linked via the base pairs, by hydrogen bonds, to form a double helix.
4. The base pairs are C-G and A –T but in RNA thymine is replaced by uracil.
5. DNA has two major functions: replication, in dividing cells, and carrying the information for protein synthesis in all cells.
6. Replication allows accurate copying of DNA for cell division.
   (No details of Meselson-Stahl required).

1.7 CELL DIVISION

1. Mitosis results in genetically identical daughter cells.
2. Candidates should appreciate the significance of mitosis in growth, cell replacement / regeneration, and asexual reproduction.
3. Candidates should understand the behaviour of chromosomes during interphase and the main stages of mitosis -, prophase, metaphase, anaphase and telophase.
4. Candidates should be able to recognise the mitotic stages from diagrams, prepared slides and photographs.
5. Meiosis occurs during sexual reproduction, when it is important that haploid gametes are produced.
6. Meiosis produces four genetically different cells and involves two consecutive divisions. (no details of the stages of meiosis are required,.)

BIOLOGY UNIT 2 (BY2)

2.1 ALL ORGANISMS ARE RELATED THROUGH THEIR EVOLUTIONARY HISTORY.

1. Biodiversity is a measure of the number of species on the planet.
2. A species is a group of organisms that can interbreed under natural conditions and produce fertile offspring.
3. The number of species per square kilometre increases as one move from the poles to the tropics. Tropical rain forests and coral reefs are the most diverse habitats on the planet
4. The fossil record shows that most species are now extinct.
5. Evolutionary history shows that biodiversity has gone through several bottlenecks called mass extinctions followed by radiations of new species.
6. Natural selection (detailed mechanism in unit 5) drives the evolution of new species.
7. Darwin's finches are an example of adaptive radiation.
8. The classification of organisms is based on their evolutionary relationships.
9. One classification concept is that of a simple phylogenetic tree.
10. All organisms can be placed into a hierarchical system of classification that includes – kingdom, phylum, class, order, family, genus, and species.
11. Organisms are more closely related with progression from kingdom to species. Taxonomy is dynamic and there are differences of opinion about whether morphology or genetics are more central for a basis of classification.
12. Candidates should understand the basic characteristics of the five kingdoms: Prokaryotae (unicellular, microscopic, no internal membrane based organelles, no nuclear membrane, cell wall not cellulose); Protoctista (eukaryotes, mainly single cell organisms, no tissue differentiation); Plantae (multicellular eukaryotes, photosynthetic, cellulose cell wall); Fungi (heterotrophic eukaryotes, rigid cell walls of chitin, reproduce by spores); Animalia (heterotrophic, multicellular eukaryotes, no cell wall, nervous coordination).

13. The animal kingdom is split into major phyla and several smaller ones. (names not required unless specified in 16 below).
14. Each phylum includes animals based on a shared basic blueprint.
15. A genus is a group of closely related species, the binomial system includes both a genus and species name.
16. The basic features of some important phyla to include:
    a. annelids (8000 named species) examples - earthworm, leech, and lugworm. Segmented worms with a closed circulatory system, hydrostatic skeleton; specialised segments responsible for different functions, thin permeable skin used for gas exchange.
    b. arthropods (1 million named species) examples – insects e.g. locust, crustaceans e.g. lobster, arachnids e.g. spider, myriapods e.g. millipedes and centipedes. These organisms are characterised by having jointed legs, an exoskeleton, and a fluid-filled body cavity. The advantages of the exoskeleton. Insects are the most successful group of animals on Earth. The presence of two pairs of wings and six legs in the adult stage is a diagnostic feature of the insects. (In the evolution of some insect groups these features may have been secondarily lost, e.g. no wings in fleas and lice.)

c. chordates (60,000 named species). Known as 'vertebrates', possessing a vertebral column or backbone (no use of term 'notochord'), well developed CNS enclosed in cranium, internal skeleton. Phylum subdivided into: fish (scales, gills, live in water), amphibian (soft moist skin, simple lungs, live on land but water needed for life cycle), reptiles (dry scaly skin, lungs, land based, lay eggs with leathery shells), birds (endothermic, lungs, feathers, forelimbs modified for flight, eggs with hard shells), mammals (endothermic, lungs, hair, double circulation, internal gestation and mammary glands, sweat glands).

17. Closely related species are recognised by their similar morphology, e.g. the homology of the pentadactyl limb in vertebrates. Analogous structures such as the wings of a bird and insect are not an indication of relatedness.
18. Biochemical methods measure the proportion of genes or proteins shared between species to estimate relatedness. Proteins are usually displayed as bands on an electrophoresis gel. Biochemical methods can reduce the mistakes made in classification due to convergent evolution.

2.2 ADAPTATIONS FOR GAS EXCHANGE

1. Living things need to obtain materials such as carbon dioxide and oxygen from the environment and remove waste from their cells to the environment.
2. Requirements may be proportional to volume however diffusion is proportional to surface area
3. In large organisms the surface area to volume ratio is much less than in very small organisms.
4. In small, unicellular organisms the surface area to volume ratio is so large that diffusion through the body surface is sufficient to supply their needs.
5. Also, distances within the body are small and transport by diffusion is again sufficient, e.g. *Amoeba*, its size and lifestyle in water enables diffusion to supply its needs.
6. Larger, multicellular organisms may have a surface area to volume ratio which is too small to supply all their needs.
7. These organisms therefore possess special surfaces for gaseous exchange, gills for aquatic environments, lungs for terrestrial environments.
8. These exchange surfaces have particular properties to aid diffusion: large surface area; thin, permeable surface.
9. The large moist area for gaseous exchange is a region of potential water loss.
10. Earthworms are multicellular, terrestrial animals restricted to damp areas. A moist body surface for diffusion, with a circulatory system and blood pigments, increase efficiency of gaseous exchange sufficient for a slow moving animal.
11. Bony fish are larger and more active. Their needs are supplied by a specialised area, the gills, with a large surface extended by gill filaments.
12. Water is a dense medium with a low oxygen content, therefore, to increase efficiency, it needs to be forced over the gill filaments by pressure differences so maintaining a continuous, unidirectional flow of water.
13. The gills have an extensive network of blood capillaries to allow efficient diffusion and haemoglobin for oxygen carriage.
14. Compared with parallel flow, counter current flow increases efficiency because the diffusion gradient between the adjacent flows is maintained over the whole surface.

15. Terrestrial vertebrates have adapted for exchange with air, a less dense medium, instead of water, so have internal lungs.
16. Internal lungs minimise loss of water and heat.
17. Amphibians have a larval form (tadpole) which develops in water and undergoes metamorphosis into the adult form.
18. The inactive frog uses its moist skin as a respiratory surface but when active uses lungs.
19. Reptiles and birds have more efficient lungs than amphibians.
20. The human respiratory system includes epiglottis, trachea, bronchi, bronchioles, alveoli, pleural membranes, ribs, intercostal muscles, diaphragm. These are involved in two functions: ventilation and exchange of gases.
21. The intercostal muscles, diaphragm, pleural membranes and pleural cavity enable ventilation movements to take place, creating volume and pressure changes that allow a continuous exchange of gases inside the body, so maintaining concentration gradients.
22. Insects have evolved a different system of gaseous exchange to other land animals.
23. Insects possess a branched, chitin-lined system of tracheae with openings called spiracles.

24. Plants rely entirely on diffusion for the exchange of gases. Leaves are therefore thin to shorten distances for diffusion and have a large surface area and are permeated by air spaces.
25. The structure of angiosperm leaf includes the cuticle, epidermis, palisade mesophyll, spongy mesophyll, vascular bundle, air space, stomata, guard cells. These structures allow the plant to photosynthesise effectively.
26. Leaf adaptation for light harvesting includes a large surface area and the ability to move by growth to the best position.
27. Palisade cells are elongated and densely arranged in a layer, or layers, and they contain many chloroplasts which arrange themselves according to the light intensity.
28. Light can pass through to the spongy mesophyll. The spaces between mesophyll cells allow carbon dioxide to diffuse to the cells and oxygen can diffuse away. The cells are moist so gases can dissolve.
29. Leaves have a cuticle to prevent water loss which also reduces gaseous exchange.
30. The presence of pores, stomata, allow water and gases through.
31. Guard cells around the stomata can change shape to open and close the stomata so helping to control gas exchange and water loss.
32. Guard cells change shape because of changes in turgor; in the light, water flows in by osmosis so the cells expand.
33. The inner wall is inelastic so the pairs of cells curve away from each other and the pore opens.
34. Pores close due to the reverse process.
35. There are several theories about the mechanism and opening is affected by changing CO_2 levels, but only the 'malate' theory is required. The movement of potassium ions from the epidermal cells into the guard cells creates a negative water potential in the guard cells. Water moves in by osmosis.
36. The movement of potassium ions is an active process requiring ATP.
37. Xerophytes may open stomata at night instead of during the day in order to conserve water, whilst other plants may close stomata during the day or night under drought conditions.

2.3 TRANSPORT

1. Multicellular animals have a transport system.
2. Insects have an open circulatory system, with a dorsal tube-shaped heart, and a fluid-filled body cavity (haemocoele).
3. The earthworm has a closed circulatory system, with blood under pressure. Organs are not in direct contact with the blood. Respiratory gases are transported in blood.
4. Mammals have a circulatory system comprising closed, double circulation and a heart with two atria and two ventricles.
5. The major blood vessels of the heart include: aorta, vena cava, pulmonary veins, pulmonary arteries, coronary arteries.
6. The heart is a specialised organ having: cardiac muscle, own blood supply, variation in thickness of wall, valves.
7. Large vessels have three main layers in the walls: tough collagen, elastic muscular layer to sustain pressure and endothelium which is smooth to reduce friction; capillary walls are one cell thick.
8. Veins have thinner muscle layer than arteries and along their length are semi-lunar valves to ensure flow in one direction.
9. Arteries have thick walls to resist pressure.
10. Arterioles adjust diameter to adjust blood supply.
11. Capillaries have a small diameter and friction with the walls slows the blood flow. Although the diameter is small, there are many capillaries in the capillary bed, providing a large total cross-sectional area which further reduces blood flow. This low velocity in very thin walled vessels enhances their ability to exchange materials with the surrounding tissue fluid.
12. Venules/veins have larger diameters and thinner walls than arterioles/arteries and the pressure is reduced; valves prevent back flow.
13. The cardiac cycle refers to a sequence of events which takes place during the beating of the heart. The sinoatrial node is spontaneously active and its excitation spreads out across the atria, causing them to contract, but is prevented from spreading to the ventricles by a thin layer of connective tissue. Excitation spreads via the atrioventricular node, through the Bundle of His to the apex of the ventricle. The Bundle branches into Purkinje fibres in the ventricle walls which carry the wave of excitation upwards through the ventricle muscle. The contraction of the ventricles is therefore delayed after the atria. The pressure changes within the atria, ventricles and aorta during the cardiac cycle can be analysed graphically. These pressure changes are responsible for the opening and closing of the valves.
14. When blood leaves the heart the highest pressures are found in the aorta and main arteries which show a rhythmic rise and fall which corresponds to ventricular contraction.
15. Friction with vessel walls causes progressive pressure drop. Arterioles have large total surface area and relatively narrow bore causing substantial reduction from aortic pressure. Their pressure depends on whether they are dilated or contracted.
16. There is even greater resistance in the capillaries with large cross sectional area.
17. The velocity of blood flow is directly related to the pressure. In the capillary beds the pressure drops further due to leakage from capillaries into tissues.
18. Return flow to the heart is non-rhythmic and the pressure in the veins is low but can be increased by the massaging effect of muscles.
19. Heart rate can be modified by hormones or the nervous system.
20. Blood components carry gases - haemoglobin carries oxygen as oxyhaemoglobin.

21. The functioning of different types of haemoglobin is demonstrated by plotting oxygen dissociation curves for normal mammalian haemoglobin compared with foetal haemoglobin.
22. Oxygen dissociation curves for llama haemoglobin and lugworm haemoglobin. Demonstrate a physiological adaptation for life in oxygen depleted conditions.
23. The release of oxygen involves the Bohr effect where the lowered pH due to dissolved carbon dioxide reduces the oxygen affinity of haemoglobin, causing it to release oxygen where it is most required.
24. Some carbon dioxide is transported in red blood cells, but most is converted in the red blood cells to bicarbonate which is then dissolved in the plasma. The chloride shift refers to the influx of chloride ions into the red blood cells to preserve electrical neutrality as the bicarbonate leaves.
25. The blood transports other substances in the plasma: digested food products, hormones, proteins, albumin, fibrinogen, antibodies and ions and it also distributes heat.
26. Water and small solutes pass through the capillary endothelium at the beginning of the capillary beds. The hydrostatic pressure here (forcing liquid out) is greater than the osmotic pressure (drawing water in). At the end of the capillary bed the hydrostatic pressure has dropped to a low value and the water potential gradient causes an inward flow. About 99% of the fluid that leaves the blood at the arterial end of the capillary bed returns at the venous end.
27. The rest of the tissue fluid is returned via the lymphatic system.
28. Candidates should be able to draw the structure of a dicotyledon root to show position of vascular tissue.
29. Most absorption of water is through the root hairs which provide a large surface area and are freely permeable.
30. Soil solution soaks into the walls of epidermal cells and travels across the cortex through the cell walls or through the spaces between cells, drawn by the transpiration stream; this is the apoplast route.
31. Water can also cross the plasma membrane by osmosis.
32. It then moves through the cytoplasm of cells via the plasmodesmata; this is the symplast route.
33. Water can also travel through the cell vacuoles; the vacuolar pathway.
34. The endodermis is a layer of cells which surround the pericycle within which lies the vascular tissue (stele).
35. The endodermis apoplast route is blocked by the Casparian band located tangentially in the cell wall and made of water-proof suberin.
36. At the Casparian band water passes across the plasma membrane and continues along the symplast route.
37. Since the xylem lacks cell contents the water is transferred to the apoplast in the pericycle.
38. Nitrogen usually enters the plant as nitrate ions/ammonium ions which diffuse along the concentration gradient into the apoplast stream but enter symplast by active transport against the concentration gradient and then flow via plasmodesmata in the cytoplasmic stream.
39. At the endodermis ions must be actively taken up to by-pass the Casparian band which allows the plant to selectively take up the ions at this point.
40. This lowers the water potential in the xylem, causing water to be drawn through the endodermis.
41. This produces a positive hydrostatic pressure inside the xylem, forcing water upwards. This positive pressure is known as root pressure.
42. Candidates should be able to draw the structure of the stem of a dicotyledon to illustrate the position of transporting tissue.

43. Xylem consists of dead, lignified tracheids and vessels with pits, supporting fibres and living parenchyma.
44. Tracheids and vessels form a continuous system of channels for water transport.
45. Water passes through the root to the xylem, up through the stem to the leaves where most evaporates.
46. The columns of water in the xylem are held up by the cohesive force between water molecules and the adhesive forces between the water molecules and the hydrophilic lining of the xylem vessels.
47. Transpiration is the loss of water from the leaves which gives rise to the transpiration stream. The continued removal of water molecules from the top of the xylem vessels results in a tension causing a pull on the xylem column.
48. Transpiration is affected by various external factors such as temperature, humidity and air movement.
49. The opening and closing of stomatal pores can alter water loss through transpiration.
50. Plants can be classified, on the basis of structure in relation to the prevailing water supply, into hydrophytes, mesophytes and xerophytes.
51. Hydrophytes, e.g. water lily, live with their roots submerged in the mud at the bottom of a pond and have floating leaves on the surface.
52. Hydrophytes have little need for support or transport tissues, have little or no cuticle and stomata only on the upper surface of their leaves. There are large air spaces present in both stem and leaf tissue.
53. Xerophytes have adapted to living under conditions of low water availability so have modified structures to prevent excessive water loss.
54. Marram Grass demonstrates the role of a xerophyte with its leaf shape, sunken stomata, thick cuticle, hairs, in reducing water loss.
55. Mesophytes are plants of temperate regions and flourish in habitats with adequate water supply. They need to survive unfavourable times of the year by shedding their leaves, surviving underground or as dormant seeds.
56. Phloem consists of sieve tubes and companion cells linked by plasmodesmata with fibres and parenchyma.
57. The products of photosynthesis are transported in soluble form (sucrose) to all parts of the plant in the phloem.
58. The leaves are a source of sugars and the growing tissues act as a sink.
59. Early evidence about translocation of solutes was obtained from ringing experiments.
60. The technique of radioactive tracing combined with using aphid mouthparts demonstrated that translocation is a rapid process.
61. Radioisotope labelling using carbon dioxide combined with autoradiography shows that sucrose is transported bi-directionally to sinks.
62. The mass flow hypothesis suggests that there is a passive flow of sucrose from source to sink. (no details required).
63. The mass flow hypothesis does not account for all observations such as movement in opposite directions at the same time and at different rates.
64. Other hypotheses have been proposed; including diffusion and cytoplasmic streaming. (no details required)

2.4 REPRODUCTIVE STRATEGIES

1. There are two types of reproduction, asexual and sexual.
2. Asexual reproduction produces individuals that are genetically identical whereas sexual reproduction produces offspring that are genetically different.
3. Genetic variability enables a species to adapt to environmental change.
4. There are advantages and disadvantages to both asexual and sexual reproduction.
5. Cells with the diploid number of chromosomes are produced by mitosis; haploid cells or gametes are produced by meiosis.
6. Males and females usually produce different sized gametes.
7. Fertilisation involves the fusion of the haploid sperm and haploid egg to produce a diploid zygote.
8. In most aquatic organisms fertilisation is external; an adaptation of land colonisation is internal fertilisation.
9. Internal fertilisation has a number of advantages.
10. In many animals the fertilised egg or zygote undergoes its development outside the body of the parent. Many eggs are produced to ensure that at least a few survive.
12. Amphibians, reptiles, birds and mammals exhibit a gradual adaptation to colonising land.
13. The gradual adaptation to life on land includes the evolution of an amniote egg in reptiles and birds. The egg has a fluid filled cavity surrounded by a membrane outside which is a protective shell which encloses the embryo within the yolk sac. Birds incubate eggs and the embryo completes its development outside the mother's body.
14. In mammals the young are retained for a considerable time in the mother's womb or uterus but there is no shell. The embryo is nourished there from the mother's blood supply via the placenta. The young are born in a relatively advanced state of development.
15. Birds and mammals also exhibit parental care and there is a relationship between the degree of parental care and the number of offspring produced.
16. Insects are a particularly abundant and extremely diverse and widespread group of animals and affect the lives of all other terrestrial organisms, particularly humans.
17. The zygote of insects develops into an intermediate form, either a nymph or a larva, before becoming an adult.
18. Nymphs resemble the adult and progress through a series of moults to become the adult; they undergo incomplete metamorphosis.
19. Larvae are different from the adult and the larval stage is followed by the pupal stage; they undergo complete metamorphosis.
20. There are similarities between the evolution of plants and animals in terms of reproductive strategies for land colonisation.
21. Flowering plants are well adapted for life on land in terms of their morphology and reproduction.
22. A key feature of their success is their relationship with animals, particularly insects, for pollination and seed dispersal.
23. The evolution of the seed with a food store enables the embryo plant to develop until leaves are produced above ground.
24. The seed also has a resistant coat that enables it to withstand adverse conditions.

2.5 ADAPTATIONS FOR NUTRITION

(There is a change of emphasis in this section compared to past BI4 – the teaching requires a comparison of the different methods of feeding according to diet and less detail on the names of the different enzymes).

1. Autotrophs use simple inorganic materials to manufacture complex organic compounds whereas heterotrophs consume complex organic food material.
2. There are a number of different types of heterotrophic nutrition.
3. An important group are the saprophytes or saprobionts, which include all bacteria and some fungi.
4. They feed by secreting enzymes onto the food material outside the body and then absorb the soluble products across the cell membrane by diffusion. This is known as extracellular digestion.
5. In heterotrophs food is processed as it passes along the gut.
6. In simple organisms, feeding on only one type of food, the gut is undifferentiated.
7. In more advanced organisms, with a varied diet, the gut is divided into various parts along its length and each part is specialised to carry out particular functions.
8. These processes are ingestion, digestion, absorption and egestion.
9. The gut wall consists of four tissue layers surrounding a central cavity - serosa, longitudinal muscle layer, circular muscle layer, submucosa and mucosa.
10. The human alimentary canal consists of buccal cavity, tongue, salivary glands, oesophagus, stomach, duodenum, ileum, colon, rectum, anus and associated organs; liver and pancreas
11. There are a number of different glands which produce digestive secretions.
12. Some of these glands are found in the wall of the gut with the secretions passing directly into the gut cavity.
13. Other glands are found outside the gut with the secretions passing along ducts into the gut cavity.
14. Organisms with a varied diet require more than one type of enzyme to carry out the digestion of the different food substrates and usually more than one type of enzyme is needed for the complete digestion of a particular food.
15. Carbohydrate digestion involves the enzyme amylase, which hydrolyses the polysaccharide; starch, into the disaccharide, maltose. Another enzyme, maltase breaks down maltose to glucose.
16. Proteins are broken down by peptidases into polypeptides, then into single units, called amino acids. Endopeptidases hydrolyse peptide bonds within the protein molecule; the peptide bonds at the ends of these short lengths are hydrolysed by exopeptidases.
17. Fats are broken down to fatty acids and glycerol by just one enzyme, lipase.
18. The specialised regions of the mammalian have different pHs therefore the different enzymes have different pH optima.
19. Mucus secretions lubricate the food as it passes along the gut and also protects the gut wall.
20. Absorption of the end products of digestion takes place in the ileum, the surface area of which is increased by villi and microvilli.
21. Glucose and amino acids are absorbed by diffusion and active transport into capillaries and then travel via the hepatic portal vein to the liver.
22. Fatty acids and glycerol are passed into the lacteal, then through the lymphatic system to the blood stream opening at the thoracic duct.

23. Most water is reabsorbed, along with soluble nutrients, in the small intestine. The colon absorbs the remaining water, together with vitamins (secreted by microorganisms in the colon) in order to produce solidified faeces.
24. Residues of undigested cellulose, bacteria and sloughed cells pass along the colon to be egested as faeces.
25. Cellulose fibre is required to provide bulk and stimulate peristalsis.
26. Glucose is absorbed from the blood by cells, for energy release in respiration, and any excess is converted to fat for storage.
27. Amino acids are absorbed for protein synthesis; excess cannot be stored so is deaminated, whereby the removed amino groups are converted to urea and the deaminated remainder is converted to carbohydrate and stored.
28. Lipids are used for membranes and hormones, and the excess is stored as fat.
29. Teeth are used in mechanical digestion in order to increase surface area for enzyme action.
30. Mammals have evolved different types of teeth with each type being specialised for a different function, incisors, canines, premolars and molars.
31. There are differences between the teeth of carnivores and herbivores reflecting their differing diets.
32. In herbivores the jaw moves in a horizontal plane whereas in carnivores the jaw moves vertically.
33. The gut of a carnivore is short reflecting the ease with which protein is digested.
34. Ruminants such as cow and sheep eat mainly grass, a large proportion of which consists of cellulose cell walls.
35. Ruminants have a specialised stomach or rumen in which mutualistic bacteria live.
36. The presence of these bacteria together with their modified gut enables ruminants to achieve a more complete breakdown of cellulose.

2.6 ADAPTATIONS FOR PARASITISM

1. Parasites are organisms that live on or in another organism, called the host, and obtain nourishment at the expense of the host.
2. The pork tapeworm, *Taenia solium*, lives inside the gut and needs to survive in a hostile environment.
3. Candidates need only a simplified description of the life cycle to appreciate how the tapeworm has adapted by having a means of penetrating the host, attaching to the host, having a thick cuticle, producing large numbers of eggs and has resistant stages to overcome the period away from the host. (A detailed knowledge of the life cycle is <u>not</u> required).

HUMAN BIOLOGY UNIT 2 (HB2)

HB 2.1 ALL ORGANISMS ARE RELATED THROUGH THEIR EVOLUTIONARY HISTORY.

1. Biodiversity is a measure of the number of species on the planet.
2. A species is a group of organisms that can interbreed and produce fertile offspring.
3. The number of species per square kilometre increases as one moves from the poles to the tropics. Tropical rain forests and coral reefs are the most diverse habitats on the planet.
4. The fossil record shows that most species are now extinct.
5. Evolutionary history shows that biodiversity has gone through several bottlenecks called mass extinctions followed by radiations of new species.
6. Natural selection (detailed mechanism in unit 5) drives the evolution of new species.
7. Darwin's finches are an example of adaptive radiation.
8. The classification of organisms is based on their evolutionary relationships.
9. One classification concept is that of a simple phylogenetic tree.
10. Organisms can be placed into a hierarchical system of classification which includes – kingdom, phylum, class, order, family, genus, and species.
11. The main features of the five kingdoms: Prokaryotae (unicellular, microscopic, no internal membrane based organelles, no nuclear membrane, cell wall not cellulose); Protoctista (eukaryotes, mainly single cell organisms, no tissue differentiation); Plantae (multicellular eukaryotes, photosynthetic, cellulose cell wall); Fungi (heterotrophic, rigid cell walls of chitin, reproduce by spores); Animalia (heterotrophic, multicellular eukaryotes, no cell wall, nervous coordination).
12. The principle of modern classification is to show how organisms may be related through evolution by the number of features they share. Organisms closely related have more features in common.
13. A taxon is an assemblage of organisms sharing some basic features. Each taxon is a level in the classification hierarchy
14. Candidates should relate the scheme of taxa within the classification system in the order of size, starting with kingdom, ending with species.
15. Organisms are more closely related with progression from kingdom to species.
16. Candidates should explain what is meant by the 'the binomial system' and realise its importance to the scientific community.
17. A 'species' is a group of organisms which can interbreed to produce fertile offspring. Fertile offspring are only produced when homologous chromosomes can pair at meiosis. Members of a species usually share similar physical characteristics.
18. A genus is a group of closely related species; the binomial system includes both a genus and species name.
19. Classify *Homo sapiens* (without reasons)
20. Human evolution is a controversial subject and various elaborate theories have been proposed to explain how humans evolved. (This is included as an example of a topic suitable for studying 'How science works').
21. Evidence for the theories has come from the discovery of fossils
22. The stages of human development to include *Homo habilis*, *Homo erectus*, *Homo sapiens neanderthalensis* and *Homo sapiens*.

23. There are two theories suggesting how modern humans have evolved; the multiregional model and the 'out of Africa' model.
24 Biochemical methods measure the proportion of genes or proteins shared between species to estimate relatedness. Proteins are usually displayed as bands on an electrophoresis gel. Biochemical methods can reduce the mistakes made in classification due to convergent evolution.

HB 2.2 THE UPTAKE OF ENERGY AND NUTRIENTS

1. In simple organisms, feeding on only one type of food, the gut is undifferentiated, but in the human with a varied diet, the gut is divided into various specialised parts along its length with each part carrying out particular functions.
2. These functions are ingestion, digestion, absorption and egestion.
3. The human alimentary canal consists of buccal cavity, tongue, salivary glands, oesophagus, stomach, duodenum, ileum, colon, rectum, anus and associated organs; liver and pancreas
4. The gut wall consists of four tissue layers surrounding a central cavity (lumen); serosa, longitudinal muscle layer, circular muscle layer, submucosa and mucosa.
5. There are a number of different glands which produce digestive secretions.
6. Some of these glands are found in the wall of the gut with the secretions passing directly into the gut cavity.
7. Other glands are found outside the gut with the secretions passing along ducts into the gut cavity.
8 Food is broken down mechanically and chemically
9. Mechanically food is broken down by the teeth, stomach and the peristaltic action of the muscular layers in the gut wall
10. The varied diet requires more than one type of enzyme to carry out the digestion of the different food substrates and usually more than one type of enzyme is needed for the complete digestion of a particular food.
11. Carbohydrate digestion involves the enzyme amylase, which hydrolyses the polysaccharide, starch, into the disaccharide, maltose. Another enzyme, maltase breaks down maltose to glucose. Other disaccharides such as lactose and sucrose are broken down into their constituent monosaccharides by their respective enzymes
12. Proteins are broken down by the enzymes pepsin in the stomach and trypsin in the duodenum. These are both produced as inactive precursors which are activated by hydrochloric acid and enterokinase respectively to prevent autolysis. These large polypeptides are then further broken down by peptidases into smaller polypeptides, then into single units, called amino acids. Endopeptidases hydrolyse peptide bonds within the protein molecule. The peptide bonds at the ends of these short lengths are hydrolysed by exopeptidases.
13. Fats are firstly emulsified by bile salts into smaller globules before being broken down to fatty acids and glycerol by lipase.
14. There are specialised regions of the mammalian gut and the different parts have different pHs because the different enzymes have different pH optima.
15. Mucus secretions lubricate the food as it passes along the gut and also protects the gut wall.
16. Absorption of the end products of digestion takes place in the ileum, the surface area of which is increased by villi and microvilli.
17. Glucose and amino acids are absorbed by diffusion and active transport into capillaries and then travel via the hepatic portal vein to the liver.

18. Fatty acids and glycerol are passed into the lacteal, then through the lymphatic system to the blood stream opening at the thoracic duct.
19. Most water is reabsorbed, along with soluble nutrients, in the small intestine. The colon absorbs the remaining water, together with vitamins (secreted by microorganisms in the colon) in order to produce solidified faeces.
20. Residues of undigested cellulose, bacteria and sloughed cells pass along the colon to be egested as faeces.
21. Cellulose fibre is required to provide bulk and stimulate peristalsis.
22. Glucose is absorbed from the blood by cells, for energy release in respiration, and any excess stored in fat cells.
23. Amino acids are absorbed for protein synthesis; excess cannot be stored so is deaminated, whereby the removed amino groups are converted to urea and the deaminated remainder is converted to carbohydrate and stored.
24. Lipids are used for membranes and hormones, and the excess is stored as fat.
25 Various diseases affect the digestive system, such as cancer, coeliac disease, diverticulosis and peptic ulcer and each has its particular treatment problems.
26. Very brief description of each disease and an indication that the causes of these diseases are complex with diet being a possible a contributory factor.

HB 2.3 GAS EXCHANGE

1. Living organisms need to obtain materials such as carbon dioxide and oxygen from the environment and remove waste from their cells to the environment.
2. Requirements may be proportional to volume however diffusion is proportional to surface area.
3. In small, unicellular organisms the surface area to volume ratio is so large that diffusion through the body surface is sufficient to supply their needs. Also, distances within the body are small and transport by diffusion is sufficient.
4. In large organisms the surface area to volume ratio is much less than in very small organisms.
5. Humans have a small surface area to volume ratio and a high rate of metabolism and have evolved a specialised gas exchange mechanism.
6. Humans have internal lungs to minimise water loss and heat.
7. The human respiratory system consists of epiglottis, trachea, bronchi, bronchioles, alveoli. pleural membranes, ribs, intercostal muscles, diaphragm. These are involved in two functions: ventilation and exchange of gases.
8. Lungs supply a large surface area, increased by alveoli, lined with moisture for dissolving of gases, thin walls to aid diffusion and an extensive capillary network for rapid diffusion and for transport to maintain diffusion gradients.
9. The intercostal muscles, diaphragm, pleural membranes and pleural cavity enable ventilation movements to take place, creating volume and pressure changes that allow a continuous exchange of gases inside the body, so maintaining concentration gradients.
10. A natural surfactant is present which lowers the surface tension so keeping the alveoli open. An artificial surfactant may be used to treat babies born prematurely before their own lungs secrete the surfactant.
11. Detailed studies of respiratory exchange can be made with a spirometer. By interpretation of the data obtained (practical work not required) the traces from a normal individual can be compared with those from sufferers with asthma and emphysema.

12. Smoking has short and long-term effects on respiration as a result of inhaling tar, nicotine and carbon monoxide.
13. Asthma causes reduction in air flow as a result of muscular spasm and constriction of the bronchioles, together with inflammation. Emphysema involves the breaking down of the walls of the alveoli so reducing the surface area.

HB 2.4 TRANSPORT TO AND FROM EXCHANGE SURFACES

1. Multicellular animals have a transport system.
2. Blood is a fluid connective tissue consisting of several types of cells suspended in a liquid matrix called the plasma.
3. There are various types of white cells (leucocytes) the function of which is to fight infection (see section 2.5). They are subdivided into granulocytes, which carry out phagocytosis and antibody-producing lymphocytes.
4. The red blood cells (erythrocytes) are smaller, more numerous, non-nucleated biconcave cells. They aid in the transport of carbon dioxide and contain haemoglobin for the transport of oxygen.
5. The blood transports other substances in the plasma: digested food products, hormones, proteins, albumin, fibrinogen, antibodies, and ions. Blood also distributes heat.
6. Mammals have a circulatory system comprising a closed, double circulation and a heart with two atria and two ventricles.
7. Every person belongs to one of four blood groups, A, B, AB or O. These letters refer to the antigens found on the red blood cells. In group O, no antigens are present.
8. Transfusion of the wrong blood group to a patient carries the risk of an antigen-antibody agglutination reaction leading to ‘clotting’ of red blood cells. The exceptions are group O people (universal donors) whose non-antigenic blood can be given to anyone, and group AB people (universal recipients) who carry both antigens and therefore will not clot introduced blood.
9. Red blood cells also carry the rhesus antigen which is present in some people (Rh positive) but not in others (Rh negative). If a Rh-ve mother is carrying a Rh+ve child, she may develop antibodies against her baby’s blood with potentially serious consequences.
10. Abnormal destruction or loss of red blood cells gives rise to anaemia. It may also be caused by an iron deficient diet or poor absorption of iron. Treatment depends on the type of anaemia and its severity.
11. The major blood vessels of the heart include: aorta, vena cava, pulmonary veins, pulmonary arteries, coronary arteries.
12. The heart is a specialised organ having: cardiac muscle, own blood supply, variation in width of wall, valves.
13. Large vessels have three main layers in the walls: tough collagen, elastic muscular layer to sustain pressure and endothelium which is smooth to reduce friction; capillary walls are one cell thick.
14. Veins have thinner muscle layer than arteries and along their length are semi-lunar valves to ensure flow in one direction.
15. Arteries have thick walls to resist pressure.
16. Arterioles adjust diameter to adjust blood supply.
17. Capillaries have a small diameter and friction with the walls slows the blood flow. Although the diameter is small, there are many capillaries in the capillary bed, providing a large total cross-sectional area which further reduces blood flow. This low velocity in very thin walled vessels enhances their ability to exchange materials with the surrounding tissue fluid.

18. Venules/veins have larger diameters and thinner walls than arterioles/arteries and the pressure is reduced; valves prevent back flow.
19. The cardiac cycle refers to a sequence of events which takes place during the beating of the heart. The sinoatrial node is spontaneously active and its excitation spreads out across the atria, causing them to contract, but is prevented from spreading to the ventricles by a thin layer of connective tissue. Excitation spreads via the atrioventricular node, through the Bundle of His to the apex of the ventricle. The Bundle branches into Purkinje fibres in the ventricle walls which carry the wave of excitation upwards through the ventricle muscle. The contraction of the ventricles is therefore delayed after the atria. The pressure changes within the atria, ventricles and aorta during the cardiac cycle can be analysed graphically. These pressure changes are responsible for the opening and closing of the valves.
20. When blood leaves the heart the highest pressures are found in the aorta and main arteries which show a rhythmic rise and fall which corresponds to ventricular contraction.
21. Friction with vessel walls causes progressive pressure drop. Arterioles have large total surface area and relatively narrow bore causing substantial reduction from aortic pressure. Their pressure depends on whether they are dilated or contracted.
22. There is even greater resistance in the capillaries with large cross sectional area.
23. The velocity of blood flow is directly related to the pressure. In the capillary beds the pressure drops further due to leakage from capillaries into tissues.
24. Return flow to the heart is non-rhythmic and the pressure in the veins is low but can be increased by the massaging effect of muscles.
25. Heart rate can be modified by hormones or the nervous system (no details).
26. Arteries stretch as a result of the pressure induced by ventricular contraction. This ‘pulse’ of high pressure can be felt in the wrist and neck, normally as a beat with a frequency of 65-70 per second. This increases with exercise and fit people tend to have a lower resting pulse and a more rapid return to normal after exercise.
27. As the ventricles contract the pressure (systolic) reaches a maximum and as the ventricles relax the pressure (diastolic) drops to a minimum. Blood pressure is recorded with a sphygmomanometer, which gives systolic and diastolic values.
28. Blood pressure can be raised if the flow in arteries is restricted by deposition of fat (atheroma), built up from cholesterol taken up from the blood, causing atherosclerosis, a major factor in heart attacks.
29. Other factors causing high blood pressure (hypertension) are poor diet, lack of exercise, stress and smoking. Hypertension increases the risk of a stroke occurring.
30. Heart function is analysed using an electrocardiogram.
31. Pressure changes in the heart are related to electrical changes that can be recorded as wave patterns on an electrocardiograph (ECG).
32. The P wave corresponds to atrial contraction, the Q, R and S waves precede ventricular contraction and the T wave represents relaxation of the ventricles.
33. A comparison of normal PQRST trace with traces showing arrhythmias such as: ventricular fibrillation; heart block; atrial fibrillation.
34. The occurrence of clots in the coronary arteries supplying the muscles of the heart is called ischemic heart disease and is often associated with stress, lack of exercise, obesity and smoking.
35. The immediate treatment of a heart attack involves the use of clot busting drugs.

36. Angioplasty involves threading micro-devices through the blood vessels to enlarge constricted arteries without resorting to major surgery.
37. An alternative is by-pass surgery in which pieces of healthy artery, usually from the leg, are grafted to the heart to improve the coronary circulation.
38. Some blood components carry gases - haemoglobin carries oxygen as oxyhaemoglobin.
39. The functioning of different types of haemoglobin is demonstrated by plotting oxygen dissociation curves for normal mammalian haemoglobin. Compare adult haemoglobin with foetal haemoglobin.
40. The release of oxygen involves the Bohr effect where the lowered pH due to dissolved carbon dioxide reduces the oxygen affinity of haemoglobin, causing it to release oxygen where it is most required.
41. Some carbon dioxide is transported in red blood cells, but most is converted in the red blood cells to bicarbonate which is then dissolved in the plasma. The chloride shift refers to the influx of chloride ions into the red blood cells to preserve electrical neutrality as the bicarbonate leaves.
42. Water and small solutes pass through the capillary endothelium at the beginning of the capillary beds. The hydrostatic pressure here (forcing liquid out) is greater than the osmotic pressure (drawing water in). At the end of the capillary bed the hydrostatic pressure has dropped to a low value and the water potential gradient causes an inward flow. About 99% of the fluid that leaves the blood at the arterial end of the capillary bed returns at the venous end.
43. The rest of the tissue fluid is returned via the lymphatic system.
44. Low blood proteins affect capillary filtration and may result in fluid retention in tissues (oedema) e.g. Kwashiorkor.

HB 2.5 HUMAN DEFENCE MECHANISMS

1. Defence against disease involves natural barriers such as the skin, skin flora and blood clotting to seal wounds along with protection by ciliated mucous membranes, lysozyme and stomach acid. Resistance to disease also depends on the general health and diet, for instance, a deficiency of vitamin C leads to weakened connective tissue causing open wounds. The skin flora offers protection by competing with pathogenic bacteria and unlike these bacteria; the flora is not easily removed by washing.
2. Localised defence involves phagocytosis and inflammation which localises any break in the barrier and destroys invading organisms.
3. Immunity is a specific systemic response acquired during a lifetime.
4. Immune responses occur as a result of antigens being recognised as foreign to the body, and may be humoral or cell mediated.
5. Humoral response involves the production of proteins (globulins) called antibodies specific to the antigen with which they form an antigen - antibody complex. Antibodies are Y- shaped, formed from four polypeptide chains.
6. The complex renders the antigen inactive in some way, such as agglutination, which allows engulfment by phagocytes.
7. Lymphocytes originate from stem cells in the bone marrow. B lymphocytes, which are responsible for the humoral response, mature in the spleen and lymph nodes. T lymphocytes, which are responsible for the cell-mediated response, are activated in the thymus gland.
8. Each B lymphocyte has receptors for the detection of its specific antigen which then stimulates the proliferation of antibody producing cells, plasma cells, and memory cells. Memory cells remain in the circulation ready to divide if the same antigen is encountered again.

9. Invasion by the corresponding antigen causes the proliferation of the T lymphocytes.
10. Among these dividing cells three functional subpopulations occur: effector cells (T killer lymphocytes) cause lysis of the target cells; helper T cells which cooperate with B lymphocytes to initiate an antibody response; memory cells which remain dormant until the host is next exposed to the antigens.
11. AIDS is caused by the immunodeficiency virus (HIV) which attacks helper T-cells in the body's immune system.
12. AIDS is the end stage of an HIV infection, the progress of the disease has three clinical stages. Firstly, HIV positive with no symptoms, secondly a low T helper cell count and finally the symptoms of clinical AIDS.
13. Immunity whether humoral or cell mediated is acquired either actively or passively.
14. Active immunity is where the individual produces antibodies and may be natural if it follows natural infection or artificial when it follows vaccination e.g. against Rubella.
15. Passive immunity is where the individual receives antibodies produced by another individual. It is called either 'natural' when transferred to the foetus via the placenta, or to the baby in breast milk, or artificial when pre-synthesised antibody is injected into an individual e.g. tetanus antitoxin. Protection is short lived because it is recognised as non-self and destroyed.
16. Exposure to an antigen is followed by a latent period then the primary response when the antibody concentration increases before decreasing again.
17. If the antigen is reintroduced or if it persists for the duration of the primary response, it stimulates a secondary response.
18. A secondary response requires a lower level of antigen and a shorter latent phase.
19. Higher concentrations of antibody are produced and the duration of peak concentrations is longer.
20. Each subsequent exposure acts as a booster until maximum levels are reached.
21. This pattern of response is mimicked by immunisation programmes such as for Rubella.

HB 2.6 PATHOGENS, SPREAD OF HUMAN DISEASE AND CONTROL OF INFECTION

1. A small percentage of parasitic microorganisms are pathogenic, causing damage to the host and this is described as disease. Some are harmless in a particular situation but are pathogenic when transferred to a susceptible area of the body or host.
2. Infectious disease may be passed or transmitted from one individual to another.
3. A carrier is a person who shows no symptoms when infected by a disease organism but can pass the disease on to another individual.
4. The place where a pathogen is normally found is its reservoir. This may be in humans or another animal and may be a source of infection.
5. A disease, which is always present at low levels in an area, is described as endemic.
6. An epidemic is where there is a significant increase in the usual number of cases of a disease often associated with a rapid spread.

7. A vaccine uses non-pathogenic forms or products of microorganisms to stimulate an immune response which confers protection against subsequent infection.
8. Antibiotics are substances produced by microorganisms which affect the growth of other microorganisms.
9. Antibiotic resistance is where a microorganism, which should be affected by an antibiotic, is no longer susceptible to it.
10. A vector is a living organism which transfers a disease from one individual to another.
11. A toxin is a chemical produced by a microorganism which causes damage to its host.
12. Antigenic types are organisms with the same or very similar antigens on the surface. Such types are sub groups or strains of a microbial species which may be used to trace infections. They are usually identified by using antibodies from serum.
13. *Salmonella sp.* is a Gram negative rod shaped bacterium; its toxins affect the gut lining causing diarrhoea and vomiting. It is spread at animal slaughter, or by contaminated food, as a result of bad hygiene practices. The organism can multiply during storage.
14. Prevention includes hygienic practices to prevent contamination, thorough cooking, cool storage conditions and prevention of contamination from carriers. Analysis of antigenic types may enable the tracing of the source of an infection.
15. Antibiotic treatment is possible but not usual to prevent the build up of resistance. A vaccine is not available as there are over 2000 antigenic types.
16. Cholera is caused by a Gram negative bacterium which is endemic in some areas of the world. Its toxins affect the gut lining causing watery diarrhoea leading to severe dehydration and frequently death. Humans act as reservoirs or carriers and contaminate water supplies in which the organism is transmitted, although it only multiplies in the human host.
17. Cholera prevention is by the treatment of water, good hygiene and the provision of clean drinking water.
18. Antibiotic treatment is possible but treatment is largely by rehydration; vaccine (killed organism or possibly genetically engineered) may provide temporary protection.
19. Tuberculosis is a bacterial disease that is again on the increase, partly due to the link with the AIDS epidemic.
20. Tuberculosis can be spread rapidly in overcrowded conditions. It is transmitted in airborne droplets when infected people cough and sneeze.
21. The most common form of TB attacks the lungs and neck lymph nodes. Symptoms include coughing, chest pain and coughing up blood.
22. Tuberculosis is prevented by a BCG vaccination programme for children.
23. Treatment involves a long course of antibiotics.
24. Influenza is caused by a virus of which there are three main sub-groups. Within each sub-group there are many different antigenic types. It infects cells lining the upper respiratory tract causing sore throat, cough and fever. Sufferers spread the disease by droplet infection.
25. Prevention includes quarantine and hygiene but influenza's mode of spread is difficult to control.
26. Antibiotics are ineffective against influenza and are only used to treat the symptoms. Annual vaccination programmes are available but due to the number of types, together with the emergence of new types, they are not always effective.

27. Malaria is caused by *Plasmodium spp*., a protoctistan parasite, endemic in some sub-tropical regions. The disease is caused mainly by two species within which are many antigenic types. The organism initially invades liver cells and then multiplies in red blood cells which burst, releasing more parasites and causing severe bouts of fever. Female mosquitoes, feeding on blood taken, act as vectors to transmit the parasite to new victims.
28. The prevention of malaria relies on a knowledge of the life cycle of both the vector and the parasite in order to exploit their weak points. A variety of methods are used either to prevent transmission (prevent biting by use of nets, clothing, insect repellent) or to destroy populations of the vector. The mosquito larvae are aquatic and can be eaten by introduced fish, or killed by drainage of breeding sites or the spraying of oil on the water surface. The adults are killed with insecticides, with bacterial infections or by sterilisation. Each of these control measures has advantages and disadvantages. (Reference should not be made to the use of DDT. If it is thought necessary to name current malaria control insecticides, reference should be made to synthetic pyrethroids).
29. Drug treatment is available but mainly to reduce the chances of infection. Vaccines have proved difficult to develop because the malarial parasite mutates and there are different antigenic types.
30. *Plasmodium* is affected by drugs when outside the cells in the blood but these have limited effectiveness and have side effects; resistance is an increasing problem. Antibodies also are only effective against the parasite when outside body cells so limiting the target stages for a vaccine.
31. Diseases caused by bacteria are treated with antibiotics which either prevent growth (bacteriostatic) or kill bacteria (bactericidal), depending on which aspect of bacterial metabolism is affected.
32. Antibiotics used medically affect bacterial metabolism but do not interfere with the host cell metabolism.
33. The shape of bacteria is due to their rigid cell wall which has a unique structure. It contains peptidoglycan (murein) consisting of molecules of polysaccharide cross linked by amino acid side chains. The cross linking provides strength and the wall protects against osmotic lysis.
34. Some bacterial walls (Gram negative) are more complex with a thinner layer of peptidoglycan surrounded by an outer layer of lipoprotein and lipopolysaccharide.
35. The Gram stain may be used to differentiate between Gram positive and Gram negative bacteria according to whether the cell wall retains crystal violet (stains purple), or not (stains red by the counterstain).
36. The Gram reaction reflects the more complex structure of Gram negative cell walls and the presence of the extra layers protects the cells from the action of some antibacterial agents such as lysozyme and penicillin.
37. Penicillin affects the formation of cross linkages in the cell wall, the wall is weakened so when osmotic changes occur, the cells lyse. Consequently penicillin is more effective against Gram positive organisms than Gram negative due to the difference in the structure of the cell wall.
38. Some antibiotics affect metabolic processes common to most bacteria, such as protein synthesis, so are effective against a broader range of bacteria.
39. Viruses are not affected due to the absence of metabolic pathways.
40. Parasites are organisms that live on or in another organism, called the host, and obtain nourishment at the expense of the host.
41. Ectoparasites are specialised to a degree but live outside the body of the host.
42. The head louse (*Pediculus*) is an ectoparasite which feed by sucking the blood from the scalp of the host.

43. Schistosomes, or blood flukes are endoparasitic flatworms specialised for living in the blood vessels supplying the intestine or bladder.
44. Transmission of the parasite occurs in freshwater when the intermediate host, the snail, releases infective larval forms.
45. The larva penetrates the skin of the human host, enters the blood stream and passes to the liver before reaching the capillary network surrounding the intestine or bladder. Many eggs are produced and are shed in the faeces or urine.
46 Ascaris is the most common human worm infection, common in tropical and sub-tropical parts of the world. The parasite lives in the small intestine.
47. The female worm produces 200,000 eggs per day and they are passed out of the body in the faeces.
48. Children can become infected after touching the mouth with hands contaminated with eggs from the soil or by ingesting contaminated food or water.
49. The pork tapeworm, *Taenia solium*, lives inside the gut and needs to survive in a hostile environment.
50. Candidates need only a simplified description of the life cycle to appreciate how the tapeworm has adapted by having a means of penetrating the host, attaching to the host, having a thick cuticle, producing large numbers of eggs and has resistant stages to overcome the period away from the host (a detailed knowledge of the life cycle is not required).
51. A detailed knowledge of the life cycle of each parasite is **not** required. Study should include the adaptations of the selected parasites to their mode of life.

A2 Level

BIOLOGY UNIT 4 (BY4)

4.1 THE IMPORTANCE OF ATP

1. Chemical energy is contained within food substances.
2. Energy may be converted from one form to another.
3. Green plants are able to convert light into chemical energy. All living organisms are able to convert chemical energy to other energy forms.
4. Candidates should be able to label the general structure of adenosine triphosphate (ATP): ribose sugar, nitrogenous base and three phosphate groups joined together.
5. Energy is required to combine ADP and phosphate to form ATP and this is an endergonic reaction.
6. Energy is released when ATP is broken down to ADP and phosphate and this is an exergonic reaction; this is linked to energy-requiring reactions e.g. active transport, muscle contraction, synthesis of organic chemicals.
7. Candidates should appreciate the importance of ATP as an energy carrier in cells and the reason why it may be called the 'universal energy currency in living organisms'.
8. Candidates should be able to define the terms 'proton' and 'electron'.
9. ATP is produced across the internal membranes of mitochondria and chloroplasts.
10. In mitochondria the internal membrane separates the intermembrane space from the matrix. In chloroplasts the corresponding membrane separates the thylakoid component from the stroma.
11. The synthesis of ATP takes place by means of a flow of protons across these membranes down a concentration gradient through the enzyme ATP synthetase (chemiosmosis).
12. To maintain the concentration of protons in the inter membrane space, proton pumps are needed which are fuelled by electron energy.
13. Candidates should be able to draw a diagram to explain the synthesis of ATP as described above.

4.2 RESPIRATION RELEASES CHEMICAL ENERGY FROM ORGANIC MOLECULES

1. Respiration is a series of enzyme-catalysed reactions which release chemical energy from organic molecules in order to synthesise ATP.
2. The four main stages of the breakdown of a glucose molecule to carbon dioxide and water are: glycolysis; link reaction; Krebs cycle; electron transport chain.
3. Glycolysis is the phosphorylation of glucose, the splitting of the 6C hexose phosphate formed into two 3C triose phosphate molecules and the oxidation of each of these to 3C pyruvate with a small yield of ATP and reduced NAD.
4. Glycolysis takes place in the cytoplasm and does not require oxygen.
5. The link reaction involves the conversion of pyruvate to acetate as a result of the loss of carbon dioxide followed by the removal of hydrogen by the reduction of NAD; the acetyl group then combines with co-enzyme A. The link reaction takes place in the matrix of the mitochondrion.
6. Each acetyl co-enzyme A enters the Krebs cycle, the co-enzyme A is regenerated and the acetate fragment is picked up by a 4C acid, to produce a 6C acid.
7. The Krebs cycle is a series of decarboxylations (removal of carbon) and dehydrogenations (removal of hydrogen) where the acetate fragment from the glucose molecule is completely broken down and the 4C is regenerated via 6C and 5C intermediates.

8. The function of the Krebs cycle is a means of liberating energy from carbon bonds to provide ATP and reduced NAD (and FAD) , with the release of carbon dioxide.
9. Reduced NAD (and FAD) deliver the hydrogen to the electron transport system in the inner mitochondrial membrane so acting as triggers for this system.
10. Candidates should be able to describe the formation of ATP via the proton pump mechanism.
11. Candidates should be able to define the terms aerobic and anaerobic respiration.
12. Candidates should understand the role of oxygen as the final electron acceptor of the electron transport chain and explain the formation of water.
13. Without oxygen the reduced NAD (and FAD) cannot be reoxidised and therefore made available to pick up more hydrogen, so under anaerobic conditions the link reaction and the Krebs cycle cannot take place.
14. Under anaerobic conditions glycolysis can take place as the NAD transfers the hydrogen to pyruvate to form lactate in animals and ethanol and carbon dioxide in plants, but there is only a very small yield of ATP.
15. Candidates should be able to state how many molecules of ATP are produced in each of the four stages of respiration and therefore the total for the complete oxidation of a glucose molecule.
16. Not all the energy of the glucose molecule is captured in ATP and there is a loss of energy as heat energy.
17. Under certain circumstances fats and proteins may be used as respiratory substrates.
18. Glycerol is converted to a 3-carbon sugar which enters the Krebs Cycle via triose phosphate.
19. Long fatty acid chains molecules are split into 2C fragments which enter the pathways as acetyl co-enzyme A.
20. The protein is broken down into its constituent amino acids which are deaminated with the removal of the NH_2 group. This leaves an organic acid that can be fed into the Krebs cycle.
21. Candidates should be able to describe similarities in mitochondrial and chloroplast membranes in terms of providing a proton gradient: proton pumps, ATP synthetase, electrochemical gradient, with high energy electrons fuelling the pumps.

4.3 PHOTOSYNTHESIS USES LIGHT ENERGY TO SYNTHESISE ORGANIC MOLECULES

1. Candidates should be able to define the term ‘photosynthesis’.
2. The main site of photosynthesis in the leaf is palisade tissue.
3. The main photosynthetic pigments found in plants are chlorophyll a and b, carotene and xanthophyll.
4. The function of these pigments is to absorb light energy.
5. The principles of chromatography as used in the separation of leaf pigments.
6. Candidates should understand the terms ‘absorption spectra’ and action spectra’ and describe the relationship of the two when considering leaf pigments.
7. Photosynthesis is a series of chemical steps which are arranged in two main stages, the light-dependent and light-independent stages.
8. Candidates should be able to describe the arrangement and function of the leaf pigments, the antennae complex and the reaction centres of photosystems I and II and their positions within the thylakoid membrane.
9. Chlorophyll a molecules, in the reaction centre, are excited and lose electrons when they absorb light energy.

10. These high energy electrons are transferred between acceptors (names not required) and used in the manufacture of ATP through cyclic and non-cyclic photophosphorylation (Z scheme).
11. The loss of electrons is a form of oxidation.
12. The hydroxide ion from the splitting of water is a source of electrons for photosystem II.
13. Molecules of water are split into hydrogen ions, electrons and oxygen and the electrons are removed to replace those lost in the chlorophyll in the photosystems. Light is responsible only indirectly for splitting water.
14. The splitting of water is referred to as photolysis. It occurs in the thylakoid space, therefore raising the concentration of protons there.
15. The reduction of NADP is brought about by the addition of electrons and hydrogen ions (protons). Since it takes place in the stroma, the concentration of protons is lowered there, further contributing to the maintenance of the electrochemical gradient.
16. The light dependent stage produces reduced NADP, ATP and oxygen. (Reduced NADP may be represented by $NADPH_2$ or $NADPH + H^+$).
17. The following steps occur in the light-independent stage (Calvin Cycle): uptake of carbon dioxide by 5C ribulose bisphosphate (Rubisco) to form 2 x 3C glycerate-3-phosphates; utilisation of ATP and reduced NADP from the light-dependent stage to reduce glycerate-3-phosphate to the 3C carbohydrate, triose phosphate and the consequent regeneration of ribulose bisphosphate which requires ATP.
18. Glucose, lipids and amino acids (with the addition of nitrogen obtained from nitrates) may be manufactured from triose phosphate (no details of chemistry required).
19. Various inorganic nutrients are needed by plants and may be limiting factors to metabolism if in short supply.
20. Nitrogen is used for the synthesis of proteins and nucleic acids so nitrogen deficiency will cause stunted growth because lack of nucleic acids will hinder cell division. Magnesium is required for chlorophyll therefore deficiency leads to chlorosis and death.

4.4 MICROBIOLOGY

1. Bacteria may be round (coccus), rod shaped (bacillus), spiral shaped (spirillum). Shape has traditionally been used for classification along with metabolic reactions.
2. The shape of bacteria is due to their rigid cell wall which has a unique structure.
3. The Gram stain may be used to differentiate between Gram positive and Gram negative bacteria according to whether the cell wall retains crystal violet (stains purple), or not (stains red by the counterstain).
4. The Gram reaction reflects the more complex structure of Gram negative cell walls
5. Microorganisms may be grown in the laboratory if supplied with suitable physical conditions, nutrients and water.
6. Organisms vary in their requirements and usually grow over a range of temperatures and pH values, with an optimum within the range.
7. Some organisms are obligate aerobes, requiring oxygen for metabolism, whilst others are obligate anaerobes and can only survive in the absence of oxygen. Many organisms will grow in either the presence or absence of oxygen, facultative anaerobes.
8. Nutrients are supplied in nutrient media and include: carbon, usually organic such as glucose; nitrogen, organic or inorganic; growth factors such as vitamins and mineral salts.
9. Glucose is normally the source of energy.

10. Aseptic techniques involve handling cultures in such a way as to prevent their contamination by unwanted organisms. However, they have a dual purpose in preventing the contamination of personnel and the immediate environment by the organisms being cultured.
11. Equipment and media must be sterilised before use by appropriate methods. Heat is commonly used, examples being the use of an autoclave at a suitable temperature ($121^{o}C$) for 15minutes, or the heating an inoculating loop in a Bunsen flame. Heat labile plastics are irradiated. Items must be protected from contamination after sterilising.
12. Direct cell counts may be total counts, which include both living and dead cells, and viable counts, which count living cells only.
13. For a viable count a known volume of organisms is added to agar plates, incubated and the colonies counted. It is assumed that one cell gives rise to one colony. This makes no allowance for clumping of cells so may cause an underestimate of numbers.
14. In both cases the original culture usually requires dilution by ten fold steps, serial dilution, in order to provide a final number within a countable range.
15. A pure culture of an organism is needed for the formation and harvesting of a pure product during and after growth in a fermenter vessel. The organism must be supplied with suitable conditions for growth and without competition for maximum efficiency.
16. The vessel should be sterilised beforehand and an appropriate sterile medium used. Filters are used to prevent contamination through the vessel's openings. Aseptic conditions and handling are required to maintain purity.
17. Forced aeration may be needed for maximum growth of aerobes and this aeration may also mix the culture to improve contact with nutrients. Mixing may be improved by a separate mixer.
18. Temperature monitoring and control are required to maintain constant conditions and water jackets remove excess heat produced during the culture process.
19. Commercially, sophisticated monitors are used to improve control of temperature and pH, and air inlets may use spargers or other devices to improve aeration.
20. For the commercial production of penicillin, the fungus *Penicillium notatum* is grown in a batch culture and the antibiotic is produced after the growth phase, when glucose is depleted. This reflects the need for the organism, when free living, to reduce competition when food sources are depleted.
21. The mycelium is removed by filtration of the culture fluid and the antibiotic purified from the residual liquid.

4.5 FACTORS CONTROLLING POPULATION SIZE

1. Ecosystems are dynamic and subject to change.
2. Candidates should be able to define the term 'population'.
3. Population numbers will fluctuate and this is dependent on various factors.
4. Population numbers are dependent on the birth and death rates, and immigration into the population and emigration away.
5. Populations will increase in size whilst death rate is lower than birth rate.
6. Some factors will slow down population growth rate and some will cause a population crash.
7. Candidates should be able to draw a generalised graph of population growth (sigmoid growth curve) and label the stages of growth as shown by a liquid culture of yeast or bacteria.
8. Candidates should be able to plot graphs of population growth rate when provided with appropriate data.
9. Candidates should be able to interpret graphs of changes in population growth rate.
10. Weather, predation, parasitism (disease), food supply, living space and competition may affect population growth.

11. The effect of density dependent factors varies with the size of the population whereas the effect of density independent will be the same regardless of the population size.
12. Candidates should be able to define the term 'carrying capacity'; explain how this is dependent on the availability of resources (which therefore act as density-dependent factors); how populations might then fluctuate about this set point.
13. Candidates should be able to describe the relative advantages and disadvantages of chemical and biological control in terms of efficiency, environmental damage, ease of use and effects on human life.
14. The advantages of chemical control include rapid eradication of a pest over a specified localised area and relative cost effectiveness. The disadvantages include the development of resistance and toxicity risks to non target organisms.
15. The advantages of biological control include its specificity, with no resistance and no environmental damage or residues. A disadvantage is the initial cost of the research required to evaluate the agent's biology, in order to introduce adequate numbers into the pest population at the optimum time. Growers must be convinced that prevention of financial loss does not require complete eradication, but that the maintenance of control may necessitate repeat application.
16. Candidates should understand what is meant by organic breakdown and describe its importance to the ecosystem in the recycling of mineral nutrients.
17. Microorganisms play an important role in the process of decay, releasing compounds of essential chemical elements from the bodies of dead organisms.
18. Candidates should be able to draw a labelled diagram of the carbon cycle linking the processes of photosynthesis, respiration, decomposition, fossilisation and combustion (link to 5.8).
19. Nitrogen is found in all amino acids from which proteins are made. Nitrogen is available to plants only in the form of ammonium and nitrate ions; these ions being taken up by the roots.
20. Candidates should link the uptake of nitrates with protein synthesis and the synthesis of nucleic acids.
21. The nitrogen cycle is the flow of organic and inorganic nitrogen within an ecosystem where there is an interchange between nitrogenous compounds and atmospheric nitrogen.
22. The main processes of the nitrogen cycle are putrefaction, nitrification, nitrogen fixation and denitrification.
23. Candidates should explain the activities of nitrifying, denitrifying and nitrogen-fixing bacteria and should know the generic names *Nitrosomonas*, *Nitrobacter*, *Azotobacter* and *Rhizobium*.
24. Ploughing and drainage are important in aeration of the soil, producing the aerobic conditions required by nitrifying bacteria.

4.6 CONTROL SYSTEMS CO-ORDINATE AND REGULATE PROCESSES

1. The term homeostasis is used to describe the mechanisms by which a constant internal environment is achieved.
2. Candidates should appreciate the importance of homeostasis. All homeostatic processes include a detector, coordinator and effector.
3. In most biological systems a negative feedback system operates.
4. Osmoregulation is the control of the water content and solute composition of body fluids.
5. Unlike the digestive breakdown products of carbohydrates and fats, the amino acids cannot be stored. Surplus amino acids, not used for the synthesis of proteins and other nitrogen molecules, are deaminated in the liver.
6. Candidates should be able to label a given diagram of the mammalian urinary system; renal artery, renal vein, kidney, ureter, bladder, urethra.

7. Candidates should be able to label a given diagram of the gross structure of kidney (L.S.); cortex, medulla, pelvis; include the position of a nephron.
8. Candidates should be able to draw and label the structure of a single nephron; afferent arteriole, efferent arteriole, glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henlé, distal convoluted tubule, collecting duct.
9. Ultrafiltration is filtration under pressure which separates small soluble molecules from the plasma.
10. The structure of the glomerulus and capsule allows ultrafiltration. The basement membrane of the capillary forms the selective barrier between the blood and the nephron and it acts as a molecular sieve.
11. A high filtration pressure is created in the glomerulus due to a difference in diameter between afferent and efferent arterioles and high blood pressure in the renal artery.
12. Selective reabsorption of glucose and Na^+ (active) and Cl^- and water (passive) in proximal convoluted tubule.
13. Candidates should understand the cell structure in relation to reabsorption: large surface area, due to microvilli and basal channels, numerous mitochondria, closeness of blood capillaries.
14. The loop of Henlé enables a counter current multiplier system to operate.
15. Na^+ and Cl^- ions are actively pumped out of the ascending limb into the tissue fluid of the medulla and diffuse into the descending limb. The ascending limb is relatively impermeable to water while the descending limb is permeable. Water leaves the filtrate osmotically and the contents of the descending limb become more concentrated. The ascending limb receives a filtrate rich in $Na^{+.}$
16. The maximum concentration occurs at the tip of the loop of Henlé, both inside and outside in the extracellular fluid.
17. The length of the loop is related to the environment of mammals.
18. The distal convoluted tubule and collecting duct have restricted permeability which is subject to hormonal control.
19. Further water reabsorption occurs through the walls of the collecting duct.
20. ADH makes the walls of the duct permeable so that water is reabsorbed and the urine has a concentration close to the concentration of the tissues near the bottom of the loop, that is, hypertonic to the general body fluids.
21. The part of the osmoregulatory system which regulates water content; detector- hypothalamus, coordinator- posterior lobe of pituitary (ADH), effector- collecting ducts of kidney.
22. Candidates should understand the mechanism of osmoregulation through ADH secretion, to show how negative feedback restores the normal osmotic concentration if blood is diluted or becomes more concentrated.
23. The environment in which an animal lives plays a part in the nitrogenous waste produced and different animals deal with its disposal in different ways.
24. Aquatic animals produce ammonia, birds and insects produce uric acid and mammals produce urea.

4.7 THE NERVOUS SYSTEM

1. Responses to all stimuli involve the reception of information and its transfer from the receptor to an effector via the nervous system.
2. Effectors are either muscles or glands.
3. Candidates should be able to draw a labelled diagram of a section through the spinal cord; central canal, grey matter, white matter, dorsal root, ventral root, sensory neurone, dorsal root ganglion, connector neurone, motor neurone, effector, meninges.
4. The reflex arc is the basis for protective involuntary actions.

5. The reflex arc is related to nerve pathways involved in voluntary actions via ascending and descending tracts in the spinal cord.
6. In simple organisms, such as *Hydra*, the sense receptors respond to a limited number of stimuli and so the number of effectors is small. Their nerve net system consists of simple nerve cells with short extensions joined to each other and branching in a number of different directions.
7. In mammals there are three types of neurones: sensory, motor and relay (connector).
8. Candidates should be able to draw a labelled diagram of a mammalian motor neurone; dendrites, cell body, nucleus, axon, myelin sheath, Schwann cell, nodes of Ranvier, nerve/axon endings.
9. Candidates should be able to describe the functions of; dendrites (carry information towards the cell body), cell body, nucleus, axon, myelin sheath, Schwann cell, nodes of Ranvier, nerve/axon endings.
10. Microelectrodes and cathode ray oscilloscopes are used to measure the potential difference across the membrane of 'giant' axons.
11. The resting potential is the potential difference between the inside and the outside of a membrane when a nerve impulse is not being conducted.
12. Resting potentials are typically minus values, the minus indicating the inside is negative with respect to the outside. The membrane is said to be polarised.
13. The sodium-potassium exchange pumps maintain the concentration and an uneven distribution of sodium ions and potassium ions across the membrane.
14. Potassium (K^+) and organic anions (COO^-) are higher inside the neurone while the concentration of sodium (Na^+) is higher outside. The membrane is more permeable to K^+ than any of the others.
15. Since the concentration of K^+ is higher than outside they diffuse out. This outward movement of positive ions means that the inside becomes slightly negative.
16. Nerve impulses are due to changes in the permeability of nerve cell membrane to K^+ and Na^+ which leads to changes in the potential difference across the membrane and the formation of an action potential.
17. Suitable stimulation of an axon results in change of potential across the membrane from a negative inside value of about –70mV to a positive inside value of +40mV. This change is called an action potential. The membrane is said to be depolarised.
18. The action potential is the result of a sudden increase in the permeability of the membrane to Na^+. This allows a sudden influx of Na^+ which depolarises the membrane.
19. A fraction of a second after this, depolarisation the K^+ diffuse out and repolarises the membrane. There is an overshoot of K^+ leaving as the K^+/Na^+ pump restores the ionic balance. This is called the refractory period during which another action potential cannot be generated so ensuring a unidirectional impulse and limiting frequency. These points should be applied to the oscilloscope trace.
20. The Na^+/K^+ pumps and the sodium and potassium channels are transmembrane proteins.
21. Changes in the intensity of the stimulus do not affect the size of the action potential and below a threshold intensity no action potential takes place. This is the ' all or nothing law'.
22. Propagation of the nerve impulse involves the stimulation of the next part of the membrane by local electric currents which cause depolarisation.
23. Myelination speeds up the rate of transmission of impulses by increasing the distance over which the local currents can bring about depolarisation. The speed of conduction is also affected by the diameter of the axon.
24. Candidates should be able to draw a labelled diagram of a synapse; synaptic knob, synaptic vesicle, mitochondria, pre-synaptic membrane, synaptic cleft, post-synaptic membrane.

25. Transmission of the impulse across the synapse is chemical rather than electrical. The chemical, or neurotransmitter, is enclosed in synaptic vesicles at the end of the axon before the synapse. The arrival of a nerve impulse depolarises the presynaptic membrane of this axon and calcium ions rush in. This influx of calcium causes the vesicles to fuse with the presynaptic membrane and releases their contents into the synaptic cleft. The neurotransmitter diffuses across the cleft and depolarises the postsynaptic membrane, propagating the impulse along the axon of the adjacent nerve cell.
26. The most common transmitter substances are acetyl choline and noradrenaline.
27. Candidates should be able to describe the role of cholinesterase in synapses.
28. Candidates should be able to describe the effects of chemicals on synaptic transmission as illustrated by organophosphorus insecticides acting as cholinesterase inhibitors. Psychoactive drugs such as cocaine and cannabis affect synapses in the brain.
29. Plants are responsive to the environment. However, their responses are slow because coordination is achieved by hormones.
30. Photoperiodism describes the influence of relative periods of light and darkness on flowering.
31. Phytochrome is the photoreceptor responsible for absorbing light. The photoperiodic stimulus is detected by the leaves of a plant.
32. Flowering plants are divided into day neutral, long-day and short-day plants according to their photoperiodic requirements prior to the production of flowers.

HUMAN BIOLOGY UNIT 4 (HB4)

HB 4.1 THE IMPORTANCE OF ATP

1. Chemical energy is contained within food substances.
2. Energy may be converted from one form to another.
3. Green plants are able to convert light into chemical energy. All living organisms are able to convert chemical energy to other energy forms.
4. Candidates should be able to label the general structure of adenosine triphosphate (ATP): sugar, nitrogenous base and three phosphate groups joined together.
5. Energy is required to combine ADP and phosphate to form ATP and this is an endergonic reaction.
6. Energy is released when ATP is broken down to ADP and phosphate and this is an exergonic reaction; this is linked to energy-requiring reactions e.g. active transport, muscle contraction, synthesis of organic chemicals.
7. Candidates should appreciate the importance of ATP as an energy carrier in cells and the reason why it may be called the 'universal energy currency in living organisms'.
8. ATP is produced across the internal membranes of mitochondria and chloroplasts.
9. Candidates should be able to define the terms 'proton' and 'electron'.
10. ADP and phosphate as well as ATP synthetase and protons from the intermembrane space are needed to make ATP,
11. To maintain the concentration of protons in the inter membrane space, proton pumps are needed which are fuelled by electron energy.
12. The synthesis of ATP takes place by means of a flow of protons across a membrane down a concentration gradient through the enzyme ATP synthetase (chemiosmosis).
13. Candidates should be able to draw a diagram to explain the synthesis of ATP as described above.

HB 4.2 RESPIRATION RELEASES CHEMICAL ENERGY FROM ORGANIC MOLECULES

1. Respiration is a series of enzyme-catalysed reactions which release chemical energy from organic molecules in order to synthesise ATP.
2. The four main stages of the breakdown of a glucose molecule to carbon dioxide and water are: glycolysis; link reaction; Krebs cycle; electron transport chain.
3. Glycolysis is the phosphorylation of glucose, the splitting of the 6C hexose phosphate formed into two 3C triose phosphate molecules and the oxidation of each of these to 3C pyruvate with a small yield of ATP and reduced NAD.
4. Glycolysis takes place in the cytoplasm and does not require oxygen.
5. The link reaction involves the conversion of pyruvate to acetate as a result of the loss of carbon dioxide followed by the removal of hydrogen by the reduction of NAD; the acetyl group then combines with co-enzyme A. The link reaction takes place in the matrix of the mitochondrion.
6. Each acetyl co-enzyme A enters the Krebs cycle, the co-enzyme A is regenerated and the acetate fragment is picked up by a 4C acid, to produce a 6C acid.
7. The Krebs cycle is a series of decarboxylations (removal of carbon) and dehydrogenations (removal of hydrogen) where the acetate fragment from the glucose molecule is completely broken down and the 4C is regenerated via 6C and 5C intermediates.
8. The function of the Krebs cycle is a means of liberating energy from carbon bonds to provide ATP and reduced NAD (and FAD) , with the release of carbon dioxide.
9. Reduced NAD (and FAD) deliver the hydrogen to the electron transport system in the inner mitochondrial membrane so acting as triggers for this system.

10. Candidates should be able to describe the formation of ATP via the proton pump mechanism.
11. Candidates should be able to define the terms aerobic and anaerobic respiration.
12. Candidates should understand the role of oxygen as the final electron acceptor of the electron transport chain and explain the formation of water.
13. Without oxygen the reduced NAD (and FAD) cannot be reoxidised and therefore made available to pick up more hydrogen, so under anaerobic conditions the link reaction and the Krebs cycle cannot take place.
14. Under anaerobic conditions glycolysis can take place as the NAD transfers the hydrogen to pyruvate to form lactate in animals, ethanol and carbon dioxide in plants but there is only a very small yield of ATP.
15. Candidates should be able to state how many molecules of ATP are produced in each of the four stages of respiration and therefore the total for the complete oxidation of a glucose molecule.
16. Not all the energy of the glucose molecule is captured in ATP and there is a loss of energy as heat energy.
17. Under certain circumstances fats and proteins may be used as respiratory substrates.
18. Glycerol is converted to a 3-carbon sugar which enters the Krebs cycle via triose phosphate.
19. Long fatty acid chains molecules are split into 2C fragments which enter the pathways as acetyl co-enzyme A.
20. Individuals are able to survive for long periods without food as they can use their reserves of carbohydrate, fat and protein.
21. Only if a person is starving is tissue protein used as a source of energy.
22. The protein is hydrolysed into its constituent amino acids which are deaminated with the removal of the NH_2 group. This leaves an organic acid that can be fed into the Krebs cycle.
23. Muscle is made up of a bundle of fibres and each fibre contains numerous myofibrils with striated appearance.
24. Candidates should be able to draw and label a diagram showing the arrangement of thin actin and thick myosin filaments in a myofibril, label sarcomere, Z line, A band (entire length of myosin filaments including overlap with actin), I band (actin only), H zone (myosin only), M line.
25. When the muscles receive a nerve impulse the sarcomeres shorten due to increased overlap, H and I bands are smaller, A stays same size.
26. The myosin and actin become linked by cross bridges.
27. The clubbed head of the myosin molecule swings back and forth with breaking and reforming of bonds to produce a ratchet mechanism.
28. As a result the actin filaments slide over myosin with no change in length of either.
29. The process is energised by hydrolysis of ATP.
30. The structure of a neuromuscular junction is similar to a synaptic knob and the post synaptic membrane is greatly folded to form a motor end-plate.
31. There are two main types of muscle fibres, slow twitch and fast twitch.
32. Slow twitch muscles are more efficient at using oxygen to generate more ATP for continuous, extended muscle contractions over a long time.
33. Slow twitch fibres help athletes run marathons.
34. Fast twitch muscles use anaerobic metabolism to create ATP and generate short bursts of strength or speed.
35. Having a greater number of fast twitch fibres can be an asset to a sprinter.
36. During exercise, glycogen, rather than fat, is the main energy source. However, glycogen is in limited supply so the body needs to use some fat to conserve glycogen.
37. Carbohydrate loading is a technique practised by athletes to increase muscle glycogen stores.

38. During intense exercise muscles rely on anaerobic respiration which produces a limited amount of energy.
39. During anaerobic respiration pyruvate is converted to lactate. There is a build-up of lactic acid in the muscles causing fatigue and cramp.
40. When oxygen becomes available again the lactic acid is broken down. The oxygen needed to break down the lactic acid is called the **oxygen debt**. At the end of the exercise the oxygen debt is repaid by breathing deeply and rapidly.
41. Training programmes improve blood supply to muscles so that they can work longer and harder before they have to switch to anaerobic respiration.
42. Training also increases the athlete's tolerance to the build-up of lactate in the tissues.

HB 4.3 PHOTOSYNTHESIS USES LIGHT ENERGY TO SYNTHESISE ORGANIC MOLECULES

1. Candidates should be able to define the term 'photosynthesis'.
2. The main site of photosynthesis in the leaf is palisade tissue.
3. The main pigment is chlorophyll and its function is to absorb light energy.
4. Photosynthesis is a series of chemical steps which are arranged in two main stages, the light-dependent and light-independent stages.
5. Chlorophyll is found in the thylakoid membranes of the chloroplast.
6. Chlorophyll molecules are excited and lose electrons when they absorb light energy.
7. These high energy electrons are transferred between acceptors (names not required) and used in the production of ATP.
8. Some of the sunlight energy is now trapped as chemical energy in an ATP molecule.
9. The synthesis of ATP from ADP and Pi by the trapping of light energy is called photophosphorylation.
10. Molecules of water are split into hydrogen ions, electrons and oxygen, and the electrons are removed to replace those lost in the chlorophyll. Light is responsible only indirectly for splitting water.
11. The splitting of water molecules is called photolysis. It occurs in the thylakoid space.
12. The reduction of the co-enzyme NADP is brought about by the addition of electrons and hydrogen ions. This takes place in the stroma.
13. The light dependent stage therefore produces reduced NADP, ATP and oxygen.
14. Reduced NADP may be represented as $NADPH_2$ or $NADPH + H^+$.
15. The following steps occur in the light-independent stage (Calvin Cycle): uptake of carbon dioxide by 5C ribulose bisphosphate (Rubisco) to form 2 x 3C glycerate-3-phosphate; utilisation of ATP and reduced NADP from the light-dependent stage to reduce glycerate-3-phosphate to the 3C carbohydrate, triose phosphate and the consequent regeneration of ribulose bisphosphate which requires ATP.
16. Glucose, lipids and amino acids (with the addition of nitrogen obtained from nitrates) may be manufactured from triose phosphate (no details of chemistry required).
17. This may be built up into a variety of plant products which provide food for humans.

HB 4.4 MICROBIOLOGY

1. Bacteria may be round (coccus), rod shaped (bacillus), spiral shaped (spirillum). Shape has traditionally been used for classification along with metabolic reactions.
2. The shape of bacteria is due to their rigid cell wall which has a unique structure.
3. The Gram stain may be used to differentiate between Gram positive and Gram negative bacteria according to whether the cell wall retains crystal violet (stains purple), or not (stains red by the counterstain).
4. The Gram reaction reflects the more complex structure of Gram negative cell walls

5. Microorganisms may be grown in the laboratory if supplied with suitable physical conditions, nutrients and water.
6. Organisms vary in their requirements and usually grow over a range of temperatures and pH values, with an optimum within the range.
7. Some organisms are obligate aerobes, requiring oxygen for metabolism, whilst others are obligate anaerobes and can only survive in the absence of oxygen. Many organisms will grow in either the presence or absence of oxygen, facultative anaerobes.
8. Nutrients are supplied in nutrient media and include: carbon, usually organic such as glucose; nitrogen, organic or inorganic; growth factors such as vitamins and mineral salts.
9. Glucose is normally the source of energy.
10. Aseptic technique involves handling cultures in such a way as to prevent their contamination by unwanted organisms. However it has a dual purpose in preventing the contamination of personnel and the immediate environment by the organisms being cultured.
11. Equipment and media must be sterilised before use by appropriate methods, commonly heat using a suitable temperature and holding time as illustrated by autoclaving at 121^{o}C for 15minutes and heating an inoculating loop in a Bunsen flame. Heat labile plastics are irradiated. Items must be protected from contamination after sterilising.
12. Direct cell counts may be total counts, which include both living and dead cells, and viable counts, which count living cells only.
13. The viable count is where a known volume of organisms is added to agar plates, incubated and the colonies counted. It is assumed that one cell gives rise to one colony. This makes no allowance for clumping of cells so may cause an underestimate of numbers.
14. In both cases the original culture usually requires dilution by ten fold steps, serial dilution, in order to provide a final number within a countable range.
15. A pure culture of an organism is needed for the formation and harvesting of a pure product during and after growth in a fermenter vessel. The organism must be supplied with suitable conditions for growth and without competition for maximum efficiency.
16. The vessel should be sterilised beforehand and an appropriate sterile medium used. During use the vessel openings must be protected from contamination by filters. Aseptic conditions and handling are required to maintain purity.
17. Forced aeration may be needed, for maximum growth of aerobes, which may also mix the culture to improve contact with nutrients. Mixing may be improved by a separate mixer.
18. Temperature monitoring and control are required to maintain constant conditions and water jackets remove excess heat produced during the culture process.
19. Commercially, sophisticated monitors are used to improve control of temperature and pH, and air inlets may use spargers or other devices to improve aeration.
20. For the commercial production of penicillin, the fungus *Penicillium notatum* is grown in a batch culture and the antibiotic is produced after the growth phase, when glucose is depleted. This reflects the need for the organism, when free living, to reduce competition when food sources are depleted.
21. The mycelium is removed by filtration of the culture fluid and the antibiotic purified from the residual liquid.

HB 4.5 FACTORS CONTROLLING POPULATION SIZE

1. Candidates should be able to define the term ‘population’.
2. Population growth in a bacterial culture is dependent on various factors.
3. Population numbers are dependent on the birth and death rates.
4. Populations will increase in size whilst death rate is lower than birth rate.

5. Some factors which will slow down population growth rate and some will cause a population crash.
6. Candidates should be able to draw a generalised graph of population growth (sigmoid growth curve) and label the stages of growth as shown by a liquid culture of yeast or bacteria.
7. Candidates should be able to plot graphs of population growth rate when provided with appropriate data.
8. Candidates should be able to interpret graphs of changes in population growth rate.
9. Temperature, parasitism (disease), food supply, living space and competition may affect population growth.
10. Candidates should be able to define the term 'carrying capacity'.
11. Candidates should be able to compare the growth curve of a bacterial culture with that of a human population growth curve.
12. Humans are able to influence their natural environment for their own benefit.
13. Humans have the potential to reduce birth rate and death rate using medical advances.
14. Humans have the potential to increase food supply but world-wide there is an inequality of production.
15. Candidates should understand what is meant by organic breakdown and describe its importance to the ecosystem in the recycling of mineral nutrients.
16. Candidates should be able to draw a labelled diagram of the carbon cycle linking the processes of photosynthesis, respiration, decomposition, fossilisation and combustion (link to 5.8).
17. Candidates should link the uptake of nitrates with protein synthesis and the synthesis of nucleic acids.
18. Candidates should know the nitrogen cycle with reference to nitrifying, denitrifying and nitrogen-fixing bacteria.
19. Candidates should know the generic names *Nitrosomonas*, *Nitrobacter*, *Azotobacter* and *Rhizobium*.
20. Candidates should understand the importance of ploughing and drainage in producing aerobic conditions needed for nitrification.

HB 4.6 CONTROL SYSTEMS CO-ORDINATE AND REGULATE PROCESSES

1. Candidates should understand the concept of homeostasis and its importance.
2. The components of a feedback system are detector, coordinator and effector.
3. Osmoregulation is the control of the water content and solute composition of body fluids.
4. Candidates should be able to explain why nitrogenous excretion is necessary.
5. Excess amino acids are deaminated in the liver of mammals.
6. Candidates should be able to label a given diagram of the mammalian urinary system; renal artery, renal vein, kidney, ureter, bladder, urethra.
7. Candidates should be able to label a given diagram of the gross structure of kidney (L.S.); cortex, medulla, pelvis; include the position of a nephron.
8. Candidates should be able to draw and label the structure of a single nephron; afferent arteriole, efferent arteriole, glomerulus, Bowman's capsule, proximal convoluted tubule, loop of Henlé, distal convoluted tubule, collecting duct.
9. Ultrafiltration is filtration under pressure which separates small soluble molecules from the plasma.
10. The structure of the glomerulus and capsule allows ultrafitration. The basement membrane of the capillary forms the selective barrier between the blood and the nephron and it acts as a molecular sieve.
11. A high filtration pressure is created in the glomerulus due to a difference in diameter between afferent and efferent arterioles and high blood pressure in the renal artery.

12. Selective reabsorption of glucose and Na^+ (active) and Cl^- and water (passive) in proximal convoluted tubule.
13. Candidates should understand the cell structure in relation to reabsorption: large surface area, due to microvilli and basal channels, numerous mitochondria, closeness of blood capillaries.
14. The loop of Henlé enables a counter current multiplier system to operate.
15. Na^+ and Cl^- ions are actively pumped out of the ascending limb into the tissue fluid of the medulla and diffuse into the descending limb. The ascending limb is relatively impermeable to water while the descending limb is permeable. Water leaves the filtrate osmotically and the contents of the descending limb become more concentrated. The ascending limb receives a filtrate rich in Na^+.
16. The maximum concentration occurs at the tip of the loop of Henlé, both inside and outside in the extracellular fluid.
17. The length of the loop is related to the environment of mammals.
18. The distal convoluted tubule and collecting duct have restricted permeability which is subject to hormonal control.
19. Further water reabsorption occurs through the walls of the collecting duct.
20. ADH makes the walls of the duct permeable so that water is reabsorbed and the urine has a concentration close to the concentration of the tissues near the bottom of the loop, that is, hypertonic to the general body fluids.
21. The part of the osmoregulatory system which regulates water content; detector- hypothalamus, coordinator- posterior lobe of pituitary (ADH), effector- collecting ducts of kidney.
22. Candidates should understand the mechanism of osmoregulation through ADH secretion, to show how negative feedback restores the normal osmotic concentration if blood is diluted or becomes more concentrated.
23. When the kidneys are damaged by injury or disease the salt and water balance of the body fluids is affected and wastes accumulate in the blood.
24. Haemodialysis involves a kidney machine and the patient's blood is passed through an artificial membrane.
25. Peritoneal dialysis uses the peritoneum which acts as a natural filter that lines the abdomen.
26. Kidney transplantation is by far the best treatment but there is a shortage of donors.
27. To prevent the recipient's immune system rejecting the kidney the tissue type and blood group of recipient and donor must be a close match.
28. On a world-wide scale there is a huge demand for donors. The fact that the donor can manage with only one kidney has fuelled the growth of a global trade in human kidneys.
29. It may be possible to genetically engineer animals of other species, such as pigs, so that their cells do not carry antigens that our immune system would attack.
30. There are ethical issues associated with this and many religious groups and individuals find it unacceptable.

HB 4.7 THE NERVOUS SYSTEM

1. Responses to all stimuli involve the reception of information and its transfer from the receptor to an effector via the nervous system.
2. Effectors are either muscles or glands.
3. Candidates should be able to draw a labelled diagram of a section through the spinal cord; central canal, grey matter, white matter, dorsal root, ventral root, sensory neurone, dorsal root ganglion, connector neurone, motor neurone, effector, meninges.
4. The reflex arc is the basis for protective involuntary actions.

5. The reflex arc is related to nerve pathways involved in voluntary actions via ascending and descending tracts in the spinal cord.
6. In mammals there are three types of neurones: sensory, motor and relay (connector).
7. Candidates should be able to draw a labelled diagram of a mammalian motor neurone; dendrites, cell body, nucleus, axon, myelin sheath, Schwann cell, nodes of Ranvier, nerve/axon endings.
8. Candidates should be able to describe the functions of; dendrites (carry information towards the cell body), cell body, nucleus, axon, myelin sheath, Schwann cell, nodes of Ranvier, nerve/axon endings.
9. Microelectrodes and a cathode ray oscilloscope may be used to measure the potential difference across the membrane of axons.
10. The resting potential is the potential difference between the inside and the outside of a membrane when a nerve impulse is not being conducted.
11. Resting potentials are typically minus values, the minus indicating the inside is negative with respect to the outside. The membrane is said to be polarised.
12. The sodium-potassium exchange pumps maintain the concentration and an uneven distribution of sodium ions and potassium ions across the membrane.
13. Potassium (K^+) and organic anions (COO^-) are higher inside the neurone while the concentration of sodium (Na^+) is higher outside. The membrane is more permeable to K^+ than any of the others.
14. Since the concentration of K^+ is higher than outside they diffuse out. This outward movement of positive ions means that the inside becomes slightly negative.
15. Nerve impulses are due to changes in the permeability of nerve cell membrane to K^+ and Na^+ which leads to changes in the potential difference across the membrane and the formation of action potential.
16. Suitable stimulation of an axon results in change of potential across the membrane from a negative inside value of about –70mV to a positive inside value of +40mV. This change is called an action potential. The membrane is said to be depolarised.
17. The action potential is the result of a sudden increase in the permeability of the membrane to Na^+. This allows a sudden influx of Na^+ which depolarises the membrane.
18. A fraction of a second after this depolarisation, the K^+ diffuses out and repolarises the membrane. There is an overshoot of K^+ leaving as the K^+/Na^+ pump restores the ionic balance. This is called the refractory period during which another action potential cannot be generated so ensuring a unidirectional impulse and limiting frequency. These points should be applied to the oscilloscope trace.
19. Changing the intensity of the stimulus affects the formation of action potentials-the ' all or nothing law'.
20. Propagation of the nerve impulse involves the stimulation of the next part of the membrane by local electric currents which cause depolarisation.
21. The Na^+/K^+ pumps and the sodium and potassium channels are transmembrane proteins.
22. Myelination speeds up the rate of transmission of impulses by increasing the distance over which the local currents can bring about depolarisation.
23. Candidates should be able to draw a labelled diagram of a synapse; synaptic knob, synaptic vesicle, mitochondria, pre-synaptic membrane, synaptic cleft, post-synaptic membrane.
24. Candidates should be able to describe the functions of; synaptic vesicle, mitochondria, pre-synaptic membrane, synaptic cleft, post-synaptic membrane in synaptic transmission. Calcium ions are needed.
25. The most common transmitter substances are acetyl choline and noradrenaline.
26. Candidates should be able to describe the role of cholinesterase in synapses.

27. Candidates should be able to describe the effects of chemicals on synaptic transmission as illustrated by organophosphorus insecticides acting as a cholinesterase inhibitor. Psychoactive drugs such as cocaine and cannabis affect synapses in the brain.
28. Motor neurone disease is caused by the degeneration of motor nerve cells that control the voluntary muscles. The cause is unknown. There is no known cure and drugs relieve symptoms; various forms of therapy help.
29. MND develops at different speeds in different individuals and affects people in different ways. Symptoms include impairment of the use of arms and legs, muscle twitch; throat and chest muscles may be affected.
30. Parkinson's disease is a slow, progressive disease caused by the death of brain cells that produce dopamine.
31. Dopamine is a neurotransmitter enabling the individual to perform smooth, coordinated movements.
32. Symptoms include repetitive shaking, slowness of movement and stiffness of muscles.
33. There is no known cure for Parkinson's but symptoms can be relieved, especially in the early stages, by replacing the missing dopamine with drugs.
34. Most strokes are due to a blood clot forming in a blood vessel supplying blood to the brain. That part of the brain becomes starved of oxygen resulting in the death of neurones in that area.
35. Effects of a stroke depend on the part of the brain affected. Symptoms include paralysis and slurred speech.
36. Immediate treatment involves administering clot-busting drugs. A daily dose of aspirin can reduce the recurrence.
37. It is important that patients receive rehabilitation therapy.
38. An individual with hypertension has an increased risk of suffering a stroke.

BIOLOGY AND HUMAN BIOLOGY UNIT 5 (BY5)

5.1 THE GENETIC CODE AND CELL FUNCTION

1. DNA has two major functions: replication, in dividing cells, and carrying the information for protein synthesis in all cells, including those in future generations of the organism.
2. Replication allows accurate copying of DNA for cell division.
3. Candidates should know the main features of semi conservative replication including the role of DNA polymerase and be able to draw a representative diagram.
4. Candidates should be able to interpret the evidence from the Meselson-Stahl experiment.
5. DNA is the starting point for protein synthesis since the sequence of bases on DNA (genetic code) determines the primary structure of a protein.
6. Each amino acid in a polypeptide is coded for by three bases, the triplet code, called the codon.
7. The portion of DNA which codes for a whole polypeptide is called a gene. This is the basis of the 'one gene one polypeptide' hypothesis.
8. Transcription is the mechanism by which the base sequence of a gene on a DNA strand is converted into the complementary base sequence of mRNA.
9. RNA polymerase links to DNA at the beginning of the sequence to be transcribed and part of the double helix unwinds. Only one of the DNA strands is used as a template.
10. As RNA polymerase moves along the strand it picks up appropriate free RNA nucleotides from the nucleoplasm (having entered the nucleus from the cytoplasm) and joins guanine to exposed cytosine, but joins uracil to the DNA's adenine forming single stranded mRNA.
11. At the end of the sequence the mRNA is detached and the DNA rewinds.
12. mRNA transfers nucleotides through the nuclear pores to the cytoplasm where it attaches to ribosomes consisting of ribosomal RNA and protein.
13. mRNA is held by a ribosome which has two transfer RNA (tRNA) binding sites. One site binds tRNA carrying the amino acid which has been joined to the growing polypeptide chain while the other site is for tRNA carrying the next amino acid in the sequence.
14. An amino acid is activated by ATP and is attached to a specific tRNA molecule which carries amino acid at one end and anticodon at the other.
15. Translation by ribosomes allows assembly of amino acids into polypeptides according to the original DNA code. A ribosomal enzyme catalyses peptide bond formation between an amino acid on one tRNA and the growing polypeptide on the other tRNA.
16. A ribosome passes along mRNA, one codon at a time, tRNA with the appropriate anticodon fills the vacant slot and the amino acid forms a peptide bond with the last member of the chain using energy from ATP, until a stop codon is reached.
17. The polypeptides may be further modified and a protein may consist of more than one polypeptide.
18. Candidates should revisit unit BY1 to understand that these modifications to the primary structure involve the Golgi body.
19. In questions on protein synthesis, candidates may be expected to interpret data, using tables listing amino acids and their corresponding mRNA codons.
20. Meiosis results in cells containing half the original number of chromosomes.
21. Candidates should understand the behaviour of chromosomes during interphase and the main stages of meiosis - prophase, metaphase, anaphase and telophase, in the first and second meiotic divisions.

22. Candidates should be able to recognise the meiotic stages from diagrams, prepared slides and photographs.
23. Candidates should be able to explain, with the aid of diagrams, how meiosis can generate variation through random assortment, crossing over and the production of haploid gametes for random fertilisation.

5. 2 SEXUAL REPRODUCTION IN HUMAN

1. Candidates should be able to label drawings of male and female reproductive systems.
2. Candidates should know the functions of: scrotum, testes, epididymis, vas deferens, seminal vesicle, prostate gland, urethra, penis, ovary, fallopian tubes (oviduct), uterus, endometrium, vagina, and urethra.
3. Spermatogenesis occurs in the testis and is a sequence of events involving mitosis and meiosis to form male gametes or spermatozoa. Candidates should relate spermatogenesis to cells visible in a T.S of a single seminiferous tubule.
4. Spermatozoa are nourished and protected by the Sertoli cells.
5. Candidates should recognise and label the structure of a mature sperm cell.
6. Oogenesis occurs in the ovary and is a sequence of events involving mitosis and meiosis to form a secondary oocyte. Candidates should be able to interpret simple drawings to illustrate the development of a follicle.
7. After sexual intercourse, fertilisation may occur in the fallopian tube.
8. Candidates should be able to explain how spermatozoa travel from the vagina to the fallopian tube.
9. Spermatozoa can fertilize an ovum only after a process, called capacitation, has taken place. This involves changes in the membrane covering the acrosome, a thin cap over the nucleus of the sperm.
10. When the sperm reaches a secondary oocyte contact with the jelly coat results in the acrosome membrane rupturing and the release of enzymes.
11. The enzymes digest the corona radiata and zona pellucida surrounding the oocyte.
12. Inversion of the acrosome results in a fine needle-like filament developing at the tip of the sperm and this pierces the oocyte membrane.
13. This process is called the acrosome reaction and enables the sperm to penetrate the oocyte.
14. Changes in the zona pellucida prevent the entry of further sperm.
15. Entry of the head of the sperm also stimulates the second meiotic division of the oocyte nucleus.
16. The nucleus of the ovum fuses with that of the sperm to form a zygote.
17. Candidates should know the terms cleavage, blastocyst and implantation. (Details of the formation of the extra-embryonic membranes not required.)
18. The developing embryo releases a hormone called Human Chorionic Gonadotrophin (HCG) which maintains the corpus luteum throughout pregnancy.
19. Candidates should know that one cause of female infertility is a blockage of the fallopian tubes and that this prevents the passage of the ovum to the site of fertilisation.
20. Pregnancy testing kits contain monoclonal antibodies bound to coloured beads and the test involves the reaction between the antibodies and the hormone, HCG in urine.

5.3 SEXUAL REPRODUCTION IN PLANTS

1. Candidates should be able to draw a diagram to show the half flower of a named regular flower (*Primula*) and label the following structures; receptacle, calyx, sepal, corolla, petal, stamen, filament, anther, carpel, ovary, ovule style and stigma.
2. Candidates should know the structure of a wind pollinated flower, Ryegrass.

3. Candidates should compare wind and insect pollinated flowers.
4. Candidates should give a simplified account of the development of pollen grains and ovule with reference to the production of a haploid nucleus by meiosis.
5. Candidates should be able to draw a diagram to show a mature ovule within a carpel and label the following structures; integuments, nucleus and micropyle.
6. Pollination is the transfer of pollen grains from the anther to the stigma.
7. Candidates should be able to describe the genetic consequences of self-pollination and cross-pollination .
8. The pollen tube grows down the style and contains the male nucleus.
9. The pollen tube enters the embryo sac via the micropyle and the male nucleus fertilises the female nucleus to give the diploid zygote. (no mention of 'double fertilisation is required)
10. Following fertilisation the development of the seed and fruit takes place.
11. The zygote becomes the embryo, consisting of plumule and radicle .
12. The integuments become the testa; micropyle remains.
13. The ovary wall becomes a fruit wall enclosing the seeds; the ovule becomes the seed.
14. Candidates should be able to draw a diagram of a broad bean (internal and external) and label; micropyle, testa, position of radicle, plumule, cotyledons.
15. Candidates should be able to compare the structure of seed (broad bean) and fruit (maize).
16. Candidates should be able to describe the germination of the broad bean, including the uptake of water and mobilisation of food reserves. Carbohydrate (starch) is hydrolysed and transported to growing points for respiration.

5.4 INHERITANCE

1. Candidates should appreciate the importance of meiosis and fertilisation in sexual reproduction giving rise to variation. Link to 5.1
2. Genetics is the study of mechanisms by which an organism inherits characteristics from its parents.
3. Candidates should give the meanings of the following; alleles (different forms of the same gene), dominant, recessive, phenotype, genotype, homozygous, heterozygous.
4. Mendel's experiments on monohybrid inheritance e.g. tall pea plants crossed with short pea plants, in diagrammatic form using suitable symbols, to include F1 and F2 generations.
5. Mendel's experiments on dihybrid inheritance e.g. pea plants bearing round, yellow seeds crossed with pea plants bearing green wrinkled seeds, in diagrammatic form using suitable symbols, to include F1 and F2 generations.
6. Candidates should be able to state Mendel's first and second laws.
7. Candidates should be able to solve problems involving monohybrid and dihybrid crosses showing workings in diagrammatic form using suitable symbols.
8. Candidates should be able to use the Chi^2 test to compare observed results with those expected and to determine whether the results are significant or non significant.
9. Candidates should be able to solve problems involving codominance (monohybrid).
10. Candidates should be able to solve problems involving linkage.
11. Candidates should be able to solve problems involving sex linkage with reference to haemophilia.
12. Mutation is a change in the amount, arrangement or structure in the DNA of an organism.
13. There are two types of mutations, chromosome mutations and gene mutations.
14. Down's syndrome as an example of chromosome mutation (non-disjunction) and sickle cell anaemia as an example of gene mutation.

15. Mutations are spontaneous random events which may provide a source of material for natural selection pressures and therefore evolution.
16. Mutation rates are normally very low. In general, organisms with short life cycles and more frequent meiosis, show a greater rate of mutation.
17. Rates of mutation may be increased by mutagens, including ionising radiations, UV and X-rays, and certain chemicals, such as polycyclic hydrocarbons in cigarette smoke. A mutagen which causes cancer is a carcinogen.
18. Candidates should appreciate the consequences of mutation in relation to protein synthesis causing a change in phenotype.
19. Oncogenes allow cells to divide uncontrollably, and this can result in cancer.

5.5 VARIATION AND EVOLUTION

1. Most characters are controlled by a number of genes and any character within a population which shows a gradation from one extreme to another, shows continuous variation. When characters are clear-cut and controlled by a single gene it is called discontinuous variation.
2. Candidates should be able to distinguish between heritable and non-heritable variation.
3. For many characteristics showing continuous variation, it is both heredity and the environment which influences the phenotypic appearance of the characteristic.
4. Various environmental factors limit the numbers in a population. Candidates should understand the significance of ‘intra and inter-specific competition’ with reference to breeding success and survival of the individual and species.
5. Examples of ‘selective agents’ include supply of food, nesting sites and climate. (Link with 4.5)
6. Candidates should be able to define the term ‘gene pool’.
7. Selection pressure can affect the frequency of alleles within the gene pool.
8. Candidates should be able to explain what is meant by ‘genetic drift’ and how it may lead to speciation.
9. Candidates should be able to understand the term ‘isolating mechanism’ and its significance in evolution.
10. Populations, and therefore gene pools, may be separated by geographical features, habitat changes, differences in behavioural mechanisms (such as courtship displays), changes in morphology (body form) and changes in breeding mechanisms. Candidates should understand how these isolating mechanisms may lead to the formation of new species.
11. Candidates should appreciate the concept of evolution and that species existing today have arisen from pre-existing species.
12. Darwin’s theory explains how existing species have arisen through modification of ancestral species by natural selection.
13. The concept of natural selection is based on the production of large numbers of offspring showing variation, and in competition there is a struggle for survival; the selective advantage of certain hereditary features enable some individuals to survive and reproduce; inheritance of those advantageous characteristics by the next generation.

5.6 APPLICATIONS OF REPRODUCTION AND GENETICS

1. Asexual reproduction involves only one organism and the individuals produced are genetically identical, i.e. a clone.
2. Cloning may be natural as in bacteria and plants grown from suckers, bulbs, corms or brought about in plants by cell culture.

3. Cloning of plants involves the growth of a plant from part of a plant or a few cells in suitable growth media. This is called micropropagation.
4. Candidates should know the steps involved in plant tissue culture; explants placed in sterile, aerated medium, cells divide by mitosis to form callus, callus is subdivided, each piece differentiates into plantlet; plantlets transplanted into sterile soil when grown to suitable size.
5. Cloning in animals may involve the splitting of an embryo before cell differentiation, and the subsequent growth of the cells.
6. Cell culture is used to produce clones of a single, identical, genetic line of cells with desirable characteristics, for example, cancer cells for medical research and production of monoclonal antibodies.
7. Tissue engineering has a number of applications. Central to this area of research is the use of stem cells.
8. A stem cell is an undifferentiated cell capable of dividing to give rise to cells which can develop into different types of specialised cells.
9. Cloning of animals may also involve the transfer of a nucleus from one individual by fusion of a somatic cell with an egg from which the nucleus has been removed, from another individual and the subsequent development of this embryo in a host or surrogate.
10. There are a number of advantages to cloning: speed of production; production of 'large' quantities; identical, genetic line of organisms.
11. There are also a number of disadvantages associated with cloning : in mammals the technique is very expensive and unreliable; in plants disease/entry of pathogens may cause problems. With the inadvertent selection of disadvantageous alleles progeny may show long term/unforeseen effects such as premature aging.
12. The Human Genome Project has determined the order of bases in the human genome as well as the identification of some genes, their sequencing and mapping.
13. This information enables scientists to scan a patient's DNA sample for mutated sequences and also to compare the sequence of DNA bases in a patient's gene to a normal version of the gene.
14. There are a number of concerns regarding the possibility of routine screening for adult onset disorders such as Alzheimer's disease and some cancers.
15. There are concerns that the risks of discrimination and social stigmatization could outweigh the benefits of testing.
16. Candidates should know about the use of genetic screening and the value of genetic counselling.
17. There are concerns regarding the ownership of genetic information and its misuse.
18. The aim of gene therapy is to treat a genetic disease by replacing defective genes in a patient with copies of a new DNA sequence.
19. There are two possible methods of replacing defective genes: somatic cell therapy and germ line therapy.
20. Candidates should know the cause and symptoms of cystic fibrosis and the day to day treatment.
21. Cystic fibrosis may also be treated with somatic cell therapy.
22. The gene delivery system, used in the treatment of cystic fibrosis involves inserting the normal genes into liposomes, which can be inhaled from an aerosol.
23. Candidates should know about the advantages and disadvantages of gene therapy.
24. Recombinant DNA is formed when a piece of 'foreign' DNA is incorporated into the circular DNA (plasmid) from a bacterium.
24. The plasmid is known as a vector and is used to introduce new DNA into bacteria.
25. The synthesis of proteins is controlled by genes which are particular lengths of DNA.
26. A restriction enzyme cuts the 'foreign' (human) DNA at particular sites into fragments. The unpaired bases at the cut form sticky ends .
27. The enzyme produces the same sticky ends in the plasmid DNA.
28. DNA ligase is an enzyme which anneals sticky ends.

29. The human DNA fragments are mixed with opened plasmids and DNA ligase to form recombinant DNA according to complementary base pairing.
30. Alternatively mRNA can be extracted from suitable cells and reverse transcriptase used to form a single strand of DNA containing the required gene.
31. DNA polymerase converts this to a double strand for incorporation into a plasmid.
32. Plasmids are added to a growing culture of bacteria but actual uptake is in a tiny proportion of cells.
33. Antibiotic resistant sequences in plasmids are used to identify and sort bacteria containing the recombinant DNA.
34. Cloning of the recombinant containing bacteria results in multiple copies of the recombinant genes.
35. There are a number of advantages in using recombinant DNA technology: e.g. the quantity production of complex proteins or peptides which cannot be made by other methods; the removal of the need to use extracts from mammalian organs.
36. There are also problems associated with its use: it is technically complicated and therefore very expensive on an industrial scale; there are difficulties involved in identifying the genes of value in a huge genome; synthesis of required protein may involve several genes each coding for a polypeptide; treatment of human DNA with restriction enzyme produces millions of fragments which are of no use; not all eukaryote genes will express themselves in prokaryote cells.
37. There are also potential hazards: bacteria readily exchange genetic material; deliberate use of antibiotic resistant genes in *E. coli* which lives in the human gut means that these genes could be accidentally transferred to human pathogens; the possibility of transfer of DNA with linked pathogenic genes, for example, oncogenes increasing cancer risks.
38. Genetically modified organisms also include plants. Certain species of bacteria naturally attack damaged plants and stimulate the growth of a tumour. Scientists can replace the tumour forming genes with useful genes.
39. Examples of GM crops are tomatoes and soya.
40. The production of herbicide resistant soybean has led to environmental as well as socio-economic problems.
41. There are a number of benefits associated with the production of GM crops: superior keeping qualities; higher yield; a substantial reduction in pesticide use on crops engineered for resistance to fungal pathogens and insect attack.
42. There are also a number of concerns: dispersal of pollen from crops engineered for herbicide resistance to wild relatives; unknown effects of eating new protein produced in crop; a reduction in biodiversity.
43. An individual's genetic fingerprint or DNA profile is different from that of other individuals.
44. Exons are regions of DNA that code for proteins. Between exons are regions of non-coding DNA called introns which contain blocks of repeated nucleotides . It is the number of times that these blocks are repeated that produces the variation in individuals.
45. Candidates should understand the original genetic fingerprinting technique using restriction enzymes, separation of different size fragments by electrophoresis, and radioactive DNA probes which produces banded patterns effectively unique to an individual which can be compared to reference samples (no further detail required).
46. Gene amplification techniques use the polymerase chain reaction (PCR) to produce a large number of copies of specific fragments of DNA. This enables tests to be carried out on very small samples accurately and more rapidly regardless of the age of the sample. Modern developments of the techniques have increased routine use .
47. Genetic fingerprinting may be used in human paternity testing and in forensic science.
48. Candidates should appreciate that there are concerns about the storage of genetic data and its access.

5.7 ENERGY AND ECOSYSTEMS

1. An ecosystem is a more or less balanced biological system comprising living (biotic) and non-living (abiotic) elements.
2. Candidates should define habitat and community, and their place within an ecosystem.
3. Photosynthesis is the source of energy for the ecosystem.
4. Photosynthetic efficiency is a measure of how well a plant is able to capture light energy.
5. Gross primary productivity (GPP) is the rate at which products are formed. A substantial amount of gross production is respired by the plant. That which is left over is called net primary production (NPP).
6. NPP represents the potential food available to primary consumers.
7. Energy is transferred through trophic levels from plants to animals, animals to animals and plants and animals to decomposers through food webs.
8. Energy is lost on transfer from one trophic level to the next.
9. Only approximately 10% of the energy ends up as herbivore biomass.
10. Candidates should understand why the efficiency of energy transfer is low.
11. Carnivores are more efficient at energy conversion because they are able to digest their high protein diets more efficiently.
12. Candidates should calculate, from appropriate information, the efficiency of energy transfer from one trophic level to the next.
13. Candidates should interpret information about trophic levels given as pyramids of energy and construct these from appropriate data.
14. Succession is the change in structure and species composition of a community over time.
15. Primary succession refers to the introduction of plants/ animals into areas that have not previously been colonised whereas secondary succession refers to the reintroduction of organisms into a bare habitat previously occupied by plant and animals
16. The different stages in a succession when particular communities dominate are known as seres.
17. All successions usually involve changes in community structure and function until a community reaches a climax of succession known as the climax community.
18. Candidates should understand the changes which take place in succession from bare rock to grassland to scrub to woodland, understanding that species diversity increases as does the stability of the community.

5.8 EFFECTS OF HUMAN ACTIVITIES AND SUSTAINABILITY.

1. ‘Superpests’ have evolved through the use of drugs and pesticides which have eliminated competition allowing a resistant form to thrive.
2. Biodiversity is the variety of species on earth; extinction is the loss of species. Many new causes of extinction and lack of biodiversity have arisen which are directly attributable to human influences such as use of resources.
3. Reasons for species becoming endangered or extinct include: natural selection; habitat destruction such as deforestation and loss of hedgerows; pollution such as PCBs and oil; hunting and collecting; competition from domestic animals.
4. Conservation is the maintenance of the biosphere and enhancement of biodiversity locally including: habitat protection by nature reserves and SSI; international cooperation restricting trade e.g. in ivory and whaling; breeding programmes by zoos and botanic gardens plus sperm banks and seed stores and reintroduction programmes such as the Red Kite in mid Wales; pollution control.
5. Conservation of species ensures the conservation of existing gene pools.

6. Candidates should appreciate the importance of conserving existing gene pools in the wild and in captivity: ethical reasons and the loss of potentially useful genes to man and the species
7. Candidates should understand the term ‘agricultural exploitation’ and the conflicts that exist between the demand for production and the need for conservation.
8. Causes of deforestation include: the use of land for agriculture by subsistence farmers and cash crops; large scale timber extraction.
9. Consequences of deforestation include: reduction in biodiversity, soil erosion, increase sediment deposits and climate change, the loss of valuable sources of plant chemicals that might have potential benefits for humans.
10. Candidates should appreciate the need for managed forests involving sustainable replanting and regeneration, protected areas to preserve species.
11. Candidates should appreciate the importance of preserving natural woodland to enhance biodiversity.
12. Candidates should appreciate the consequences of over-fishing on fish stocks.
13. Methods are employed to regulate fishing, including imposing fishing quotas, exclusion zones and restricted mesh sizes.
14. Fish farming may be one solution to the problem of overfishing but it is the cause of many problems: these include disease, overuse of antibiotics, pesticides and eutrophication.
15. The carbon cycle may be affected by human activities such as deforestation and combustion leading to an enhanced greenhouse effect.
16. Climate change and global warming may be the result of human activities.
17. The carbon footprint may be seen as the total amount of carbon dioxide attributable to the actions of an individual or a product or service over a period of one year.
18. Scarcity of water may become a major issue for future food production and there will be a need to develop drought resistant crops.
19. The increased use of nitrogen containing fertilisers has had some harmful effects on both aquatic and terrestrial ecosystems.
20. On agricultural land there has been a reduction in species diversity in grassland.
21. Nitrate leached into rivers has caused eutrophication and algal blooms.
22. Digging drainage ditches has had a detrimental effect on habitats resulting in reduced biodiversity.
23. The use of biofuels may be a way of reducing greenhouse gas emissions. However, environmentally a major adoption of biofuels will reduce biodiversity.

6 PRACTICAL WORK FOR AS AND A2

The assessment objectives for AS and A2 practical work are the same. The expectations and opportunities for practical work are rooted within the subject content in the relevant AS and A2 units. Therefore for A2 content from BY4, HB4 and BY5 should be used whilst ecology, fieldwork and appropriate statistical analysis could be included. The investigative work is set by the centre and marked by WJEC.

Setting the investigation
The practical assessment comprises a concise written report of an investigation set by the centre which is carried out by candidates. The investigation must be relevant to the AS or A2 specification as appropriate. Methods from the previous WJEC specification may provide a guide to the types of investigation considered suitable. As a guide to how the new practical assessment differs from the current scheme, Appendix 1 provides examples of current exercises which have been modified for the new format. The guiding principle, however, is that any investigation should allow access to each of the marking criteria.

Centres may choose to provide an outline method. If this method is a standard procedure or investigation then **no** approval is required. However, Centres must submit the outline plan of any candidate devised or unusual investigation for approval by the WJEC before its use as an assessed investigation. A proforma is provided for this purpose (Specification appendix 6). WJEC reserves the right not to accept any such work that has not been submitted for, and granted, prior approval. Details of any information given to candidates as a starter scenario or any outline method provided to candidates must be included for reference by the marker.

There is no requirement that individual candidates in a centre carry out different investigations but centres are required to ensure that the work is solely that of each candidate.

Candidates should carry out and analyse one complete investigation for assessment. However, candidates should carry out other investigations and practical work throughout the course. The practising of the Investigation to be used for assessment beforehand is not allowed as it would not be an effective use of time nor a worthwhile educational experience. It is envisaged that candidates would be trained throughout the course in the skills required for practical work and to think about the requirements associated with the practicalities of the investigation including issues of planning time management. This would include points such as considering a feasible range of variables or number of repeats and whether this would result in any compromises in the data produced whist addressing the aim of the investigation. Such points could provide a source of issues to be raised during the analysis stage.

The use of computer simulations or packages to generate data is not recommended as the ethos of the assessment is actually carrying out practical work. This is reflected by the mark scheme and using such packages may therefore prevent access to some of the marking points.

Any candidates resitting a practical unit, either AS or A2, must resubmit a new investigation and not reuse any previous work which has been used for assessment purposes.

Assessment conditions

The investigation is to be conducted under supervised conditions. It is **not** an open-book exercise. If a statistical analysis is required e.g. during a field work investigation, then candidates are permitted to consult necessary statistical formulae and tables.

The practical assessment overall should be viewed in the same way as a theory examination with regard to security and malpractice and candidates warned to this effect. The experimental work and written report should be solely that of the candidate. The teacher may intervene to aid progress where absolutely necessary but must annotate the work to this effect and recognise that any associated marks can not be awarded as a result.

The practical work, at both AS level and A2 level, must be carried out between 1 January and 15 May of the year in which it is submitted for assessment. Centres must inform WJEC of the date(s) when practical assessments are to be carried out. This information will be requested via an annual circular in September.

For assessments from summer 2015, all candidates in a centre should plan the investigation in the same single assessment session. If this is not possible, then alternative investigations should be set for each subsequent assessment session required. It is still permissible for candidates to be split into smaller groups to carry out the remainder of the investigation in a number of different assessment sessions.

As stated above, the planning section of the investigation should be completed in a single assessment session by all candidates, if at all possible. Some centres may choose to complete the entire investigation in one morning session. It is however, more likely that there may be an interval between the planning session and the remainder of the investigation to allow for any equipment implications to be considered. It is recognised that some investigations may require more time than others to complete, but investigations should be completed within a reasonable time limit.

In between sessions the written work should be retained and stored securely by the teacher. Subsequent amendments to the written work by the candidates are not permissible and continued redrafting of the work is not allowed. After the practical assessments have taken place the completed answer booklets must be securely stored by the exams officer before they are sent to WJEC. No access to the completed answer booklets is to be given to teachers or candidates after the assessments have taken place.

Experimental Results

Candidates are not expected to generate the perfect or ‘text book’ set of results and a negative result is still a result. It is anticipated that candidates generate their own individual results and analyse their own data commenting on any unusual, anomalous or unexpected results.

In some exceptional circumstances e.g. where a single individual in a class has been unable to generate any data in an investigation which has provided data for the rest of the group then the teacher could intervene and provide data in an unstructured format for analysis. The work must be annotated to this effect and the details of the circumstances explained on form B/H A (appendix 3). The data provided must address the original aim of the candidate’s investigation.

If a centre wishes to plan an investigation, either laboratory based or fieldwork, with the intention of pooling class results then **prior approval must be sought** using the appropriate form (Specification appendix 6). It must be noted in this instance that, for a valid use of data to be made, then candidates should carry out the same investigation using the same aim, variables, range etc. If these conditions were to be provided, candidates may not be able to access some of the marking points. If candidates were not directed to a common investigation then they may access the marking points but the validity of the exercise would need to be taken into account and questioned.

Any details which may be needed in order to help the examiner to interpret the situation with regard to the setting up, carrying out or writing up should be explained on form B/H A (appendix 3) and sent off with the scripts for marking.

Requirements of the report
The written work would follow the pattern of the marking scheme using the headings: Aim/Prediction; Experimental design; Results; Analysis; Further work.
Candidates may have access to the mark scheme for training purposes but not during the assessment or its writing up. During the assessment a display may be provided for the class showing only the checklist given in Appendix 5. This is also given on the inside cover of the provided answer booklet No other reference materials are allowed. The use of an examination answer booklet for the report is required in order to prevent subsequent amendments to the work. Note that from October 2010 specific BY3/BY6 answer books are provided. Further copies may be obtained from WJEC or downloaded from the website.

Full details of the method used must be included. If an outline method has been provided then this should be included with the candidates work.

The use of a computer during the writing is acceptable but not recommended as it may cause an authentication problem. If a computer is used, then the teacher must be completely certain that it is the work of the candidate concerned and that no collaboration has taken place. Under no circumstances should the work be removed to be completed elsewhere. The use of computer generated graphs is not recommended as these would prevent access to some of the marking points.

The report should be concise, relevant to the investigation in hand and address the marking criteria. It is unlikely that a candidate would need more than one answer booklet for their report.

Microscopy
It is anticipated that, during the course, candidates would produce drawings of a variety of specimens in order to acquire the appropriate skills. The best **one** produced by each candidate should be submitted for assessment. However, the repeated drawing and redrafting of a drawing of an individual specimen is not an efficient use of time and is not acceptable.

Assessment at AS: candidates are required to submit **one low power plan** (no cells drawn), with magnification noted, labelled and with a suitable heading, from any slide relevant to/suggested in the AS specification.

Assessment at A2: candidates are required to submit **one drawing**, labelled and with a suitable heading, from a slide relevant to/suggested in the A2 specification (not bacteria). The drawing of the specimen may be produced using either a low or high power objective lens and the magnification used must be noted on the drawing.

The calibration of the microscope must be included along with the measurement of an indicated tissue or structure with a size calculation. The magnification chosen **must be noted on the candidate's work**. Drawings of specimens examined at low power, as in ecological investigations, are also acceptable.

The labels expected are those from standard GCE textbooks. The use of obscure or uncommon labels will not gain credit.

Microscope work, including the calibration, may be carried out with reference to textbooks, notes or histology atlases.

Form B/HA (appendix 3) should be used to notify the examiner of any unusual features of the specimens or graticules used.

BY3 and BY6

Points to note, in brief, when preparing the candidates:

- work should allow access to the current marking criteria;
- candidates should carry out their own plan;
- candidates should not be given excess information which denies them access to the marking points;
- if results are shared, or given for some reason or any other help given, then candidates own results should be identified and the reason why results/help are given should be stated clearly;
- avoid the use of 'rate' unless of course you specifically train them to calculate it;
- encourage them to give units to the independent and dependent variables;
- get the candidates to explain why they repeat experiments as opposed to just saying that they are going to repeat;
- encourage the candidates to reason why a control experiment is necessary;
- tables should have clear headings with units in the title and not the body of the table;
- 2 decimal places is generally sufficient (except some statistical tests);
- remember to have linear scales with the origin labelled;
- ensure they make adequate observations on consistency, preferably derived from error bar interpretations;
- make the best possible use of all biological knowledge aiming to be coherent and accurate in its presentation to gain all available marks for the particular section;
- encourage the preparation of conclusions that draw on several pieces of information;
- promote the full description of expected results in the further work, either in a short accurate paragraph or fully annotated graph;
- produce several pieces of microscopy work during the year, selecting the best one for submission;
- on the day(s) of the examination allow candidates access to the scenario sheet and the list of section headings as outlined in appendix 4 of the guidance notes (note nothing else is permissible. Exceptions apply for statistics and microscope work, see earlier);
- the report should be written in BY3/BY6 examination answer booklets;
- redrafting and later amendments of the work is not allowed.

Points to consider before you post scripts:

- has the cover sheet on each candidate's work been completed and signed?
- have the individual parts of a candidate's work been named and included?
- has a copy of the scenario sheet been included?
- has one microscope drawing been attached, including candidate's details?
- there should be a register of candidates entered for the unit with your Examination Officer, has it been included? [The Examination Officer should also have your address labels]
- to avoid any damage to the scripts they should ideally be sent to the examiner in a script envelope or a course work bag, again available from your Examination Officer.
- work should meet the deadline for submission.

Standard Terminology/Definitions

Various biological definitions and interpretations are provided in the booklet entitled 'Biological Nomenclature' available from Society of Biology.
Standard definitions of terms used in practical investigations for GCE and GCSE are provided in the booklet entitled 'The Language of Measurement' published by ASE. The text is endorsed by all Awarding Bodies and extracts are available from www.gettingpractical.org.uk

Generic marking schemes for investigative work

As centres may submit a variety of investigations for assessment the following is an indication of the likely mark allocation for BY3 and BY6. However, it may not be entirely applicable in every case and slight modifications may be made, therefore, for particular circumstances.

Generic marking scheme for AS investigative work

Clarification in italics

Aim/Prediction (P)

(a) Correct identification of 2 variables
(i.e. that which is actually being measured) [1]

(b) Linking 2 variables with direction [1]
(*Reference to rate is only accepted if rate is also plotted on the graph.)*

Experimental Design (D)

Variables **identified**:

(a) Independent variable [1]
(clearly stated as such)

(b) **Appropriate** range of stated values and units for independent variable. [1]

(Range usually covers 5 values and each must be stated, examiners will not look for them in tables or graphs. Implied statements are not sufficient e.g. I used 5 concentrations between 1 and 20 vol. Use of terms such as 'vol' and 'percentage' as derived units of concentration may be misleading and needs to be consistent, particularly if using hydrogen peroxide i.e. in context does 'vol' refer to volume used or concentration? The relationship of any dilutions derived from an original stock solution must be made clear e.g. a 2% dilution of the stock solution rather than just a 2% dilution).

(c) Dependent variable with units [1]
(clear statement needed and appropriate units)

(d) 2 named controlled variables relevant to task [1]
with appropriate values for each [1]

(e.g. pH is not sufficient; a value such as pH 7 is needed. Reference to room temperature is too vague, a value must be given. Relevance to task must be considered e.g. use of 37^{o}C is only appropriate if human enzymes are being used/ pH 7 is not appropriate for pepsin.)

(e) Explanation why repeat readings are needed [1]

(e.g. reference to uncertainty in measurement/use of mean or confidence in representative sampling)
(allow: reference to improvement in reliability)

(f) Suitable control experiment [2]

Reference to inactivating one feature e.g. boiling enzyme (1)

Reason as to why there is no appropriate control available (1)

Reference to same conditions/volumes (1)

Explanation of use of control (1)).

2 from 4

(An appropriate control for water potential could be boiled tissue. For investigations involving the activity of an enzyme then the control must be the inactivation of the enzyme activity by boiling and cooling not just its substitution by water. If there is no appropriate control then an explanation of the use of experimental controls would access a mark. A control experiment could be planned and described but not actually carried out.)

(g) Identification of the main hazard for the investigation carried out and description how one of these hazards may result in a risk of injury plus normal laboratory procedure to minimise the risk described. [1]

(The main hazard for the actual investigation should be described e.g. if an experiment involves hydrogen peroxide then it would be expected that hydrogen peroxide would be the main hazard rather than something else, such as hot water. Actually using a piece of equipment is the hazard rather than merely the presence of the equipment itself. Normal laboratory procedures are required to minimise the risk rather than some unusual remedy which is not normally available e.g. steel gloves. No marks for general laboratory rules)

Results (R)

Recording of results:

(a) Correct column headings in table [1]
(time must be qualified)

(b) Appropriate units in headings, not in body of table [1]

(c) Sufficient repeats or explanation if not feasible to do them [1]

(Sufficient repeats is usually taken as 2 or 3 but it may depend on results e.g. if there is wide variation then more would be recommended, but if there is no variation then fewer are appropriate).

(d) Appropriate recording of results – reflects uncertainty commensurate with instruments used/calculation of mean/rate, as appropriate. [1]

(Appropriateness depends on the investigation e.g. number of decimal points being quoted. Use of minutes and seconds is ambiguous e.g. 2.25 could be 2 min 25 sec or 2 min and a quarter of a minute. Seconds only are therefore clearer).

Processing of data in a suitable format i.e. graphs as appropriate:
(the publication 'Biological Nomenclature' is taken as defining good practice):

(e) Correct axes labelled, [1]
(Both axes labelled).

(f) sufficient use of grid [1]
(At least half of grid should be used).

(g) Correct units, both axes [1]

(h) Suitable linear scale used on each axis including origin [1]
(Linear scale must include a figure at the origin. It may not always be 0 and break lines are acceptable if used appropriately).

(i) Accurate plotting of points (1 mark lost for each error) [2]

(j) Suitable and accurate joining of points with no extrapolation [1]
(line of best fit or point to point (through centres joined using ruler) as appropriate)

Analysis (A)

(a) Description of general trend shown by results [1]
(Trend must relate to candidates own results.)

(b) Comment made on the consistency/spread of results/possible use of range bars plus comment. [1]
(*Comment could be a reference to overlapping range bars but comment must match data.)*
(allow: reference to reliability [but not accuracy])

(c) Statement commenting on sources of uncertainty/accuracy of measurement. [1]
(Refers to equipment used or could relate to procedure).

(d) Two suitable suggestions for improvement [2]
(Improvements must relate to the experiment actually being carried out; not reference to more repeats)

(e) Concise explanation of results using relevant and sound biological knowledge or comparison with theoretical expectations if appropriate [5]
(Concise, coherent statements are needed.)

Majority of relevant principles showing coherence/understanding (5)

Most principles, no coherence (4)

Some major principles given (3)

Some major principles missing and some misunderstanding (2)

Little relevant information given (1)

No relevant information, information misunderstood (0)

(f) Using your biological knowledge and your results draw a suitable valid conclusion related to your aim [1]
(The conclusion is a statement by the candidate that pulls together biological knowledge or aim with their results possibly quoting figures from their results.)

(g) Teacher signature/comment on cover sheet about level of practical skill shown, possibly using data collected compared to data collected by teacher or theoretical expectation, as a guide [1]

Further work (F)
Plan an investigation using a different independent variable
(An increased range of the previous investigation is not acceptable. A detailed method in full is not required.)

(a) Independent variable [1]

(b) Two appropriate controlled variables each plus values [2]
(One of which must be different from those previously used. One of the controlled variables could be the variable previously investigated.)

(c) Suggest the expected results of this investigation [1]
(The expected results could include a sketch graph.)

Total 38 marks

Microscopy

Candidates are required to submit 1 drawing only, selected from those completed throughout the course:
(Only one drawing is required. Examiners will not select from multiple drawings submitted.)

Quality (Q) Clean, single, sharp, complete lines and no shading or individual cells. [2]

Proportion (P) Two measurements marked on drawing, across different tissue layers, with values in eye piece units. [1]

Drawing the correct proportions of all tissues [1]

(Candidates are required to include 2 lines on the drawing, measured in eye piece units, which will be measured and used to judge proportion. The end of the lines must accurately mark the edge where the layer was measured. One line may be across the whole specimen and one across a tissue layer. A key to explain the meaning of the abbreviation 'epu' is required, if used, and the lines should preferably terminate in short 'ends' at right angles to the main line, although small 'dots' are acceptable. The lines should be on the drawing and not alongside. Label lines without an arrowhead are preferable. Endothelium should be shown as two lines)

Labelling (L) The correct identification of all main tissues/structures by unambiguous labelling [2]
(2 marks are awarded if the majority of appropriate labels are present, 1 mark if some are missing.)

Note: The drawing should include an indication of the magnification used to observe the specimen and a title indicating the specimen being observed.

Total 6 marks

Generic marking scheme for A2 investigative work

Marks in bold type are extra to those required for AS.

Clarification in italics

Aim/Prediction (P)

(a) Correct identification of 2 variables
(i.e. that which is actually being measured) [1]

(b) Linking 2 variables with direction [1]
(*Reference to rate is only accepted if rate is also plotted on the graph.)*

Experimental Design (D)

Variables **identified**:

(a) Independent variable [1]
(clearly stated as such)

(b) **Appropriate** range of stated values and units for independent variable. [1]

(Range usually covers 5 values and each must be stated, examiners will not look for them in tables or graphs. Implied statements are not sufficient e.g. I used 5 concentrations between 1 and 20 vol. Use of terms such as 'vol' and 'percentage' as derived units of concentration may be misleading. The relationship of any dilutions derived from an original stock solution must be made clear e.g. a 2% dilution of the stock solution rather than just a 2% dilution).

(c) Dependent variable with units [1]
(clear statement needed and appropriate units)

(d) 2 named controlled variables relevant to task [1]
with appropriate values for each [1]
(e.g. pH is not sufficient; a value such as pH 7 is needed. Reference to room temperature is too vague, a value must be given. Relevance to task must be considered e.g. use of 37^{o}C is only appropriate if human enzymes are being used/ pH 7 is not appropriate for pepsin.)

(e) Explanation why repeat readings are needed [1]
(e.g. reference to uncertainty in measurement/use of mean or confidence in representative sampling)
(allow: reference to improvement in reliability)

(f) Suitable control experiment [2]

Reference to inactivating one feature e.g. boiling enzyme (1)

Reason as to why there is no appropriate control available (1)

Reference to same conditions/volumes (1)

Explanation of use of control (1).

2 from 4

(For investigations involving the activity of an enzyme then the control must be the inactivation of the enzyme activity by boiling and cooling not just its substitution by water. A control experiment could be planned and described but not actually carried out.)

(g) Identification of the main hazard for the investigation carried out and description how one of these hazards may result in a risk of injury plus normal laboratory procedure to minimise the risk described. [1]

(The main hazard for the actual investigation should be described Actually using a piece of equipment is the hazard rather than merely the presence of the equipment itself. Normal laboratory procedures are required to minimise the risk rather than some unusual remedy which is not normally available. No marks for general laboratory rules)

Results (R)

Recording of results:

(a) Correct column headings in table [1]
(time must be qualified)

(b) Appropriate units in headings, not in body of table [1]

(c) Sufficient repeats or explanation if not feasible to do them [1]
(Sufficient repeats is usually taken as 2 or 3 but it may depend on results e.g. if there is wide variation then more would be recommended, but if there is no variation then fewer are appropriate).

(d) Appropriate recording of results – reflects uncertainty commensurate with instruments used/calculation of mean/rate, as appropriate. **[2]**
(Appropriateness depends on the investigation e.g. number of decimal points being quoted. Use of minutes and seconds is ambiguous e.g. 2.25 could be 2 min 25 sec or 2 min and a quarter of a minute. Therefore a sensible approach in context is needed.

Processing of data in a suitable format i.e. graphs as appropriate:
(the publication 'Biological Nomenclature' is taken as defining good practice):

(e) Correct axes labelled, [1]
(Both axes labelled).

(f) sufficient use of grid [1]
(At least half of grid should be used).

(g) Correct units, both axes [1]

(h) Suitable linear scale used on each axis including origin [1]
(Linear scale must include a figure at the origin. It may not always be 0 and break lines are acceptable if used appropriately).

(i) Accurate plotting of points (1 mark lost for each error) [2]

(j) Suitable and accurate joining of points with no extrapolation [1]
(line of best fit or point to point (through centres joined using ruler) as appropriate)

Analysis (A)

(a) Description of trend shown by results [1]
(trend must relate to candidate's own results).

(b) Comment made on the consistency of results [1]
(allow: reference to reliability [but not accuracy])

(c) Comments on use or suitability of error bars [**1**]
(e.g. ref. overlap of error bars but must match data)

(d) Statement commenting on sources of uncertainty/accuracy of measurement. [1]
(could relate to equipment or procedure)

(e) Two suitable suggestions for improvement [2]
(Improvements must relate to the experiment actually being carried out; not reference to more repeats)

(f) Concise explanation of results using relevant and sound biological knowledge or comparison with theoretical expectations if appropriate [**6**]
(concise coherent statements required)

Majority of relevant principles showing coherence/understanding (6)

Most principles, limited coherence (5)

Some major principles given, no coherence (4)

Some major principles missing and some misunderstanding (3)
(Or 3 max if AS level interpretation)
Little relevant information given (2)

No relevant information, limited understanding (1)

(g) Using your biological knowledge and your results draw a suitable valid conclusion related to your aim. [**3**]
(could include figures from their results)

Accurate conclusion using all relevant information (3)
(i.e. reference to prediction, knowledge, results)

Conclusion reached using some relevant information (2)

Inappropriate conclusion or no relevant information used (1)

(h) Teacher signature/ comment on cover sheet about level of practical skill shown, possibly using data collected compared to data collected by teacher or theoretical expectation, as a guide [1]

Further work (F)

Plan an investigation using a different independent variable
(An increased range of the previous investigation is not acceptable. A detailed method in full is not required.)

(a) Independent variable [1]

(b) Two appropriate controlled variables each plus values [2]
(One of which must be different from those previously used.
One of the controlled variables could be the variable previously investigated.)

(c) Suggest the expected results of this investigation [**2**]
(The expected results could include a sketch graph.)

Total 44 marks

Modification of BY6 criteria for field work experiments/statistics

Many points are common with the A2 mark scheme above so common interpretation applies.

Aim / Prediction (P)

(a) correct identification of variables (1)

(b) variables linked with direction (1)

Experimental design (D)

(a) Independent variable stated (1)
(clearly stated as such)

(b) either (i) give range with 5 sample values.
or (ii) if comparison state the single difference and give values. (1)
(Values may be approximate, as the results have yet to be taken.)

(c) Dependent variable with units. (1)
(Clear statement needed and appropriate units.Explanation of lack of units is to be given if dependent variable is a calculated value, such as Disney's, Simpson's or Lincoln index.)

(d) Controlled variables.

(i) Two of the most important should be named, with approximate values stated for each.
("Amount" acceptable in relation to trampling.) (1)

(ii) Explanation of fact that these variables cannot be controlled but are monitored to ensure they are close enough to have no effect on dependent variable. (1)

(e) Explanation why repeat readings are needed [1]
(e.g. reference to uncertainty in measurement/use of mean or confidence in representative sampling. If repeats not possible e.g. in testing a correlation or measuring at sites along a river, discussion needed of idea of contribution of the number of pairs of results.)
(allow: reference to improvement in reliability)

(f) Explanation of use of control (1)

Reason as to why there is no appropriate control available (1)

(g) Identification of the main hazard for the investigation carried out and description how one of these hazards may result in a risk of injury plus procedure to minimise the risk described. [1]

(The main hazard for the actual investigation should be described Actually using a piece of equipment is the hazard rather than merely the presence of the equipment itself. Normal procedures are required to minimise the risk rather than some unusual remedy which is not normally available.

Results (R)

Recording

(a) correct column headings in table (1)

(b) appropriate units in headings, not in body of table (1)

(c) sufficient repeats of dependent variable or explanation if not feasible to do them (1)

(d) Appropriate recording of results – reflects uncertainty commensurate with instruments used. [1]
(Appropriateness depends on the investigation e.g. number of decimal points being quoted. Use of minutes and seconds is ambiguous e.g. 2.25 could be 2 min 25 sec or 2 min and a quarter of a minute. Therefore a sensible approach in context is needed.

calculation (as appropriate mean/ rate) (1)

Graph or Statistics

Graph

(e) correct axes labelled (1)
(both axes labelled)

(f) sufficient use of grid
(*At least half of grid should be used).* (1)

(g) correct units on both axes (1)

(h) suitable linear scale on each axis, including origin (1)
(Linear scale must include a figure at the origin. It may not always be 0 and break line are acceptable if used appropriately).

(i) accurate plotting of points or bars in bar chart (-1 per error) (2)

(j) suitable and accurate line or explanation that none appropriate if correlation is being tested
(line of best fit or point to point as appropriate) (1)

Statistics

(e) explanation why this test has been chosen (1)

(f) null hypothesis (1)

(g) correct calculation of test statistic e.g. t, r_S, U (2)

(h) number of degrees of freedom / level of significance / confidence limits quoted (1)

(i) statement of critical value lower or higher than calculated value (1)

(j) accept or reject null hypothesis at 0.05 level of significance (1)

Analysis (A)

(a) description of trend shown by graph / explanation of meaning of statistics (1)
(trend must relate to candidate's own results).

(b) comment in relation to sample size / consistency of results (1)
(allow: reference to reliability [but not accuracy])

(c) comment/explanation on use or suitability in relation to range/error bars / standard deviation / error bar overlap/if use correlation – why no error bars are possible. (1)
(*comment must match data)*

(d) statement on sources of uncertainty/accuracy in relation to equipment / procedure / use of level of significance (1)

(e) two suitable improvements e.g. increase in sample size, choice of quadrat area if not previously tested (2)
(must relate to experiment actually being carried out)

(f) Concise explanation of results using relevant and sound biological knowledge [6]
(concise coherent statements needed)

Majority of relevant principles showing coherence/understanding (6)

Most principles, limited coherence (5)

Some major principles given, no coherence (4)

Some major principles missing and some misunderstanding (3)
(or Max 3 if AS level interpretation)

Little relevant information given (2)

No relevant information, limited understanding (1)

(g) Using your biological knowledge and your results draw a suitable valid conclusion related to your aim [3]
(could include figures from their results)

Accurate conclusion using all relevant information (3)
(i.e. reference to prediction, knowledge, results)

Conclusion reached using some relevant information (2)

Inappropriate conclusion or no relevant information used (1)

(h) Teacher signature/comment on cover sheet about level of practical skill shown, possibly using data collected compared to data collected by teacher or theoretical expectation, as a guide [1]

Further work (F)

Plan an investigation using a different independent variable
(An increased range of the previous investigation is not acceptable; detailed method in full not required.)

(a) Independent variable [1]

(b) Two appropriate controlled variables each plus values [2]
(One of which must be different from those previously used; one of the controlled variables could be the variable previously investigated.)

(c) Expected results of this investigation [2]
(expected results could include a <u>labelled</u> sketch graph.)

Total 44 marks

Microscopy

Candidates are required to submit only 1 drawing plus calibration and size calculation selected from those completed throughout the A2 course:
(Only one drawing is required. Examiners will not select from multiple drawings submitted.)

Labelling (L)	The correct identification of all main tissues/structures by unambiguous labelling. *(mark awarded if the majority of appropriate labels are present)*	[1]
Calibration (C)	Calibration of the microscope for the appropriate objective lens. *(Steps clearly laid out; figures used and abbreviations explained)*	[3]
Measurement (M)	Identification of point of measurement on drawing and calculation of actual measurement (mm/µm) of measured region.	[2]

The drawing should include an indication of the magnification used to observe the specimen and a title indicating the specimen being observed.

Total 6 marks

Safe, skilful working

It is anticipated that the skills of candidates will be developed throughout the course by frequently carrying out a variety of practical/microscope work and receiving tuition in practical techniques. By the time the assessment takes place, therefore, the level of skills and safety awareness should be sufficiently developed in order to ensure that candidates work in a safe, ordered manner, showing good laboratory/field practice and using common biological equipment in a competent, precise and skilful manner. The level of skill used will also be reflected in the results shown and a comment reflecting the skill shown by a student, possibly involving a comparison of results obtained by the teacher in the same investigation, is required.

Submission

The completed practical work should be submitted to an external assessor for marking during the summer term by a date provided annually.

An appropriate, completed authentication cover sheet (appendix 2 and 3) should accompany each candidate's work. Note that the BY3/BY6 answer booklets include the cover sheet.

The cover sheet should be signed and dated by both the teacher and candidate to verify it is the candidate's own work.

In addition, the teacher may include a comment to verify that whilst in the laboratory/field the candidate worked in a safe and skilful manner. A teacher signature on the cover sheet will be taken as this verification.

Any unauthenticated work or work which has not been verified for safety cannot be marked and will be returned to the centre. Failure to submit the signed authentication sheet could result in the candidate being recorded as absent or 0 marks (JCQ guidance) and will deny access to the mark for safe working.

The drawing and calibration, as appropriate, should be submitted for marking at the same time as the investigative work.

The name of a person to whom the work should be sent for marking will be sent out by WJEC annually, normally in late April.

The report of the investigation plus microscope work and associated information, as stipulated above, should be sent to the nominated person to arrive by the due date as published annually, normally in early May.

Any loose pages, such as the microscope work, must be clearly labelled with the candidate's name and centre and attached to the answer booklet (preferably using untied treasury tags). Any unattributed work cannot be marked and candidates will therefore penalise themselves as a result.

Work must not be submitted in large or bulky folders/files or plastic wallets. It is anticipated that a single answer book should be sufficient for the report.
The authenticity of any word processed work as being solely that of the candidate must be assured.

Microbiological practical work

Working with microorganisms requires special consideration regarding safety, over and above the normal safety requirements in a laboratory.

Microbiological practical work is carried out using aseptic technique in order to handle cultures and equipment in a safe and correct manner. Aseptic technique has two purposes, as far as possible, to ensure safety for laboratory workers and secondly to prevent contamination of the cultures being studied. The following notes indicate good practice they do not constitute a manual of laboratory techniques.

Safety:
Only a small percentage of microorganisms are pathogenic but it is safer to assume that any culture may contain pathogens and so appropriate precautions should be taken. There are two main routes by which infection in the laboratory may occur; the mouth, via the hands, and the respiratory tract. It is therefore important to prevent contamination of surfaces and the atmosphere.

- A laboratory coat should always be worn as it may be autoclaved if spills occur.
- Cuts on exposed skin, especially hands, should be covered by a waterproof dressing.
- No 'hand to mouth' activities should occur e.g. eating, smoking, licking labels, sucking or chewing pens etc.
- No pipetting by mouth, a pipette filler should always be used.
- The mouth of bottles and tubes should be passed through a Bunsen flame when opened.
- An inoculating loop should be heated in the cool part of the flame first in order to prevent the spattering of any loop contents.
- Bottle tops/plugs after removal should be held in the hand at all times and not placed on the bench.
- The bench should be disinfected before and after use, therefore it is usual to keep the bench clear of clutter and not to use a heat proof mat under a Bunsen burner.
- All spills must be mopped up and disinfected appropriately.
- All used cultures and equipment should be sterilised/disinfected after use/before disposal.
- Hands must always be washed before leaving the laboratory.

Prevention of contamination:

- All apparatus should be sterilised and then protected from contamination before use.
- An inoculating loop should be sterilised, before and after use, by heating to red heat along the entire length of the wire by being held at an almost vertical angle in a Bunsen flame.
- Sterile surfaces should not be exposed to air any longer than necessary and open bottles should be held at an angle from the vertical.
- The open mouths of bottles/tubes should be flamed before and after transfer of contents.
- Sterile surfaces e.g. inside Petri dishes and objects should not be touched by non-sterile hands, objects or surfaces. For instance, bottle tops should be held in the hand and not placed on the bench. In general, whilst holding a container in one hand, the plug or cap is removed by gripping it with the fourth and fifth fingers of the opposite hand. This leaves the first three fingers of this

'opposite' hand free to manipulate loop/pipette etc. (whilst holding the cap) in the open container still held in the first hand.

- Preferably, during manipulations, plates should be placed upside down on the bench with the bottom half, containing agar, being lifted out of the lid, then turned over for streaking etc. The lid remains inverted on the bench to receive the bottom half afterwards.

In a school laboratory certain other precautions are required:

- The lid of an inoculated agar plate should be held in place by two pieces of tape (not around the circumference since this would exclude air) and the lid should not be removed after incubation.
- Incubation must take place at a maximum of 30^{o}C to prevent the growth of pathogens.
- Only certain non-pathogenic (category 1) cultures should be used.

Microscope work

Microscope work involves making a simple record of what is observed and it is expected that appropriate skills will be developed during the course.

A drawing of a specimen should be a straightforward and accurate representation of that specimen, as actually seen. It should be a record of the specimen and not an artistic interpretation. No shading is required or inclusion of structures which are not actually observed. A drawing made using a sharp, good quality HB pencil is preferable, as mistakes can be rubbed out. A simple line drawing should be made using clear, firm, unbroken, narrow lines, appropriately labelled via ruled label lines which do not cross. Lines should not be 'sketched' or feathery and should meet accurately without leaving unwarranted gaps and without overlap. The drawing should be of a suitable size to show all relevant features, show correct proportions and have a title, with scale or magnification included as appropriate. Any points included to indicate where two measurements have been taken must be shown directly on the drawing and not alongside as this introduces a source of error. Labels expected are those commensurate with this level of study and what can be seen using an average microscope. The inclusion of obscure structures and labels which are not commonly used is not required.

Marking points include:
the use of clear, continuous, unbroken lines with no shading;
correct relative proportions;
correct labelling of distinctive features

Annotated examples of microscope drawings follow the calibration below. The first drawing shows clear lines and accurate representation of the specimen whilst the others give the reasons why marks are lost.

The calibration of the microscope involves the use of an eyepiece graticule and stage micrometer at a stated magnification. All workings should be shown:

At x40 magnification

(1) X eyepiece divisions = Y stage divisions

(1) 1 stage division = Z mm/µm (correct units required)

(1) X eyepiece divisions = Y x Z mm/µm

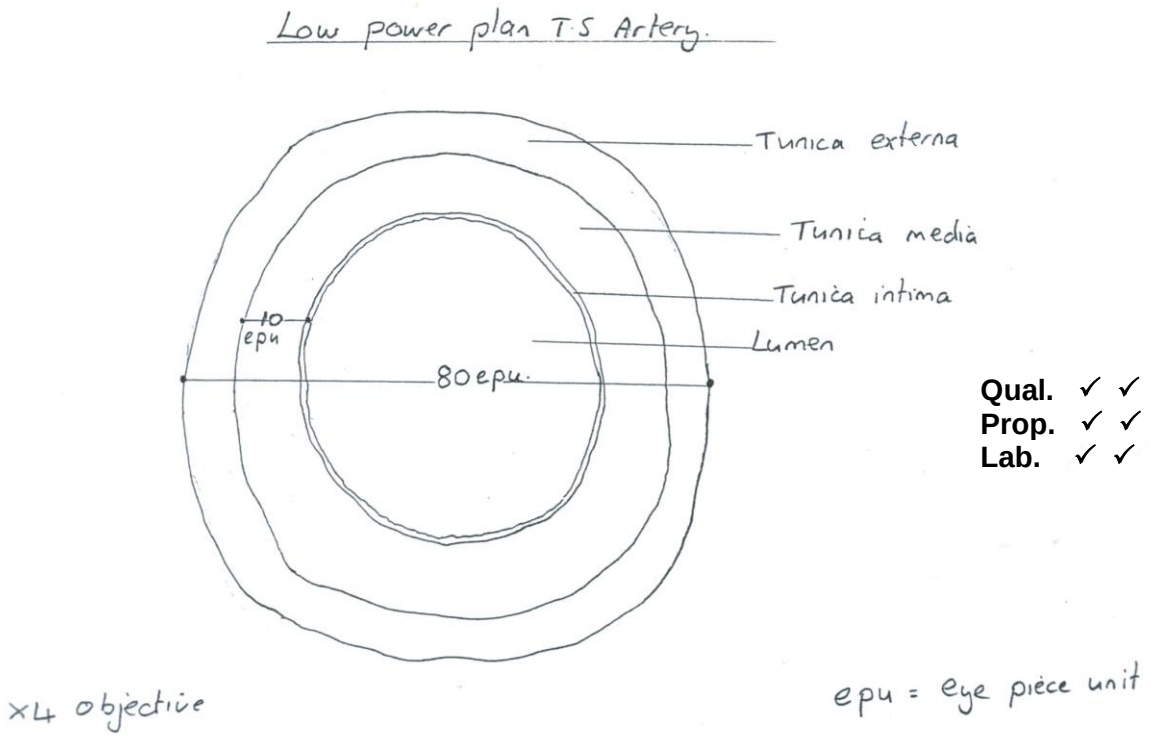
1 eyepiece division = $\frac{Y \times Z}{X}$ mm/µm

This is a continuation of the previous mark allocation, as is the use of abbreviations, such as epu, which are not acceptable unless explained.

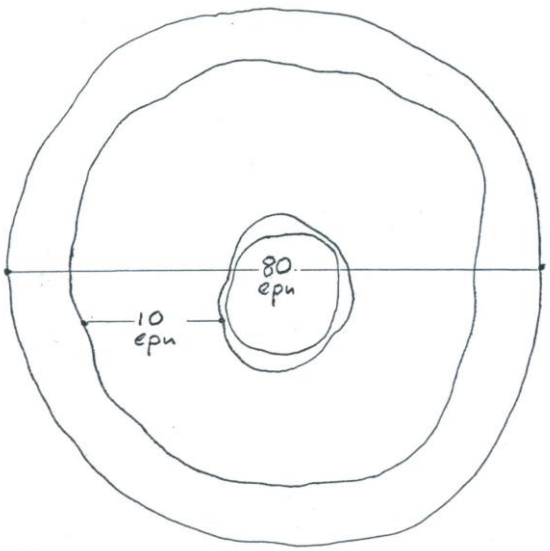
When determining the size of a specimen a specific dimension should be indicated and a calculation might be given as follows:

Diameter of the section = X eyepiece divisions

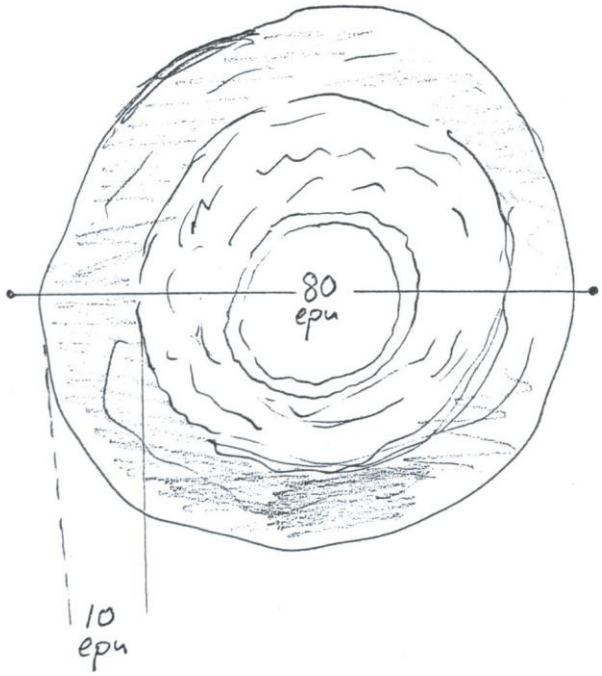
= (**X** x calibrated value) mm/µm



Qual. ✓ ✓
Prop. ✓ ✓
Lab. ✓ ✓

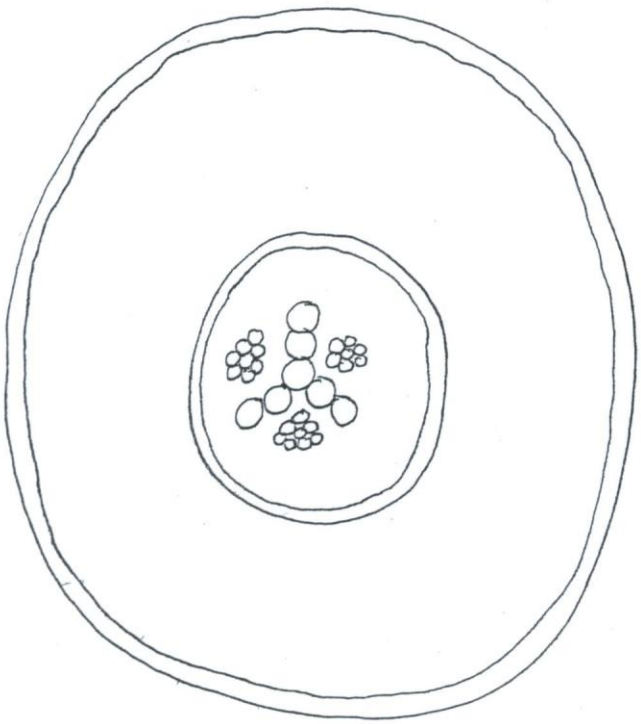


No marks for proportion,
Tunica media drawn Incorrectly.
Tunica intima variable thickness – incorrect.



Both marks lost for quality – Overlapping sketchy lines, shading.

Both marks lost for proportion – 80 epu line extends past drawing, 10 epu lines taper. Tunica externa – too thick.



One quality mark deducted – cells shown.

Example of typical layout of microscope exercise for A2

Using microscope, eye piece graticule, stage micrometer and a prepared slide of transverse section (TS) of a leaf (*Ligustrum)*.

(a) Make a labelled, low power, plan drawing of the section you can see under your microscope, to include the midrib.

(b) Measure the diameter of widest point of the midrib in eyepiece units (X-X).

Measurement of X-X = …… eyepiece units.

Measure the thickness of the mesophyll layer in eyepiece units (Y-Y).

Measurements of Y-Y = …… eyepiece units.

On your diagram in part (a) indicate clearly the two measurements you have taken, labelling them X-X, and Y-Y respectively.

(c) Calibrate the eyepiece graticule at low power. Record all your workings in the space below. All your steps must be clear and easy to follow.

(d) Convert measurement X-X from eyepiece units to an actual measurement using the calibration value from part (c).

Use the workings from earlier parts of this question for the calculation. All steps must be recorded clearly and be easy to follow.

7 USEFUL TEXTS AND WEBSITES

Useful texts

Student Revision Guides for AS and A2 are published by WJEC and available only from the WJEC bookshop.
Examiners reports are available to download after each examination session.

There are many texts available which cover all specifications and which may be being updated by publishers. Currently suitable texts include: Gareth Williams, Advanced Biology for You and Toole and Toole, Understanding Biology (Stanley Thornes).
Practical:
Practical Biology for Advanced Level (1994), Roberts, Reiss & King, Nelson (ISBN 0 17 448225 6)
Tools, Techniques and Assessment in Biology (1999), Adds, Larkcom, Miller & Sutton, Nelson (ISBN 0 17 448273 6)
Skills in Advanced Biology (1995), Volume 2 (series of three) Observing, Recording and Interpreting, Garvin, Stanley Thornes (ISBN 0 8595 0 817 X)
Advanced Biology Statistics (1996), Edmondson & Druce, Oxford Univ. Press (ISBN 0 19 914654 Statistical and Data Handling Skills in Biology(1999), Ennos, Longman
Maths Skills for Advanced Sciences(2000), Price, Oxford Univ. Press (ISBN 0 19 914740 X)
Control of Substances Hazardous to Health (COSHH) Regulations (1994) (ISBN 0 7176 1308 9)
Topics in Safety (1998), Association for Science Education (ISBN 0 86357 104 2)
CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services) Laboratory Handbook, Cleapss, School Science Service, Brunel University, Uxbridge UB8 3PH

Useful websites

http://www.sustainable-development.gov.uk/
http://www.sd-commission.org.uk/
www.field-studies-council.org
www.britishecologicalsociety.org/articles/education
www.ethics.sandiego.edu/Applied/Environment
www.microbiologyonline.org.uk
www.ase.org.uk
www.beep.ac.uk
http://www.defra.gov.uk/environment/sustainable
www.nature.com
http://www.wildlifetrusts.org
www.newscientist.com
www.wellcome.ac.uk/bigpicture
www.bbc.co.uk/science/hottopics
www.royalsoc.ac.uk/scienceinsociety
www.wellcome.ac.uk/labnotes
www.webanatomy.net/histology
www.saps.org.uk
www. practicalbiology.org
www.gettingpractical.org.uk
www.societyofbiology.org

APPENDIX 1 Examples of suitable types of practical investigations

A suitable scenario or some background could be provided as follows:

BY3 (a) Catalase is an enzyme that increases the rate of decomposition of hydrogen peroxide, a toxin found in cells. The reaction is shown below:

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$$

Catalase is found in high concentration in germinating mung beans.

Plan an investigation into factors affecting catalase activity and state the aim of your investigation. The following is a possible outline method.

germinated mung beans,
Pestle and mortar,
specimen tubes
2% hydrogen peroxide
filter paper discs,
Forceps,
Stopwatch,
syringe
Distilled water,
Paper towel.

(1) Grind 2 mung beans with 5 cm^3 of distilled water to produce a smooth paste containing the enzyme.

(2) Using forceps, dip a filter paper disc into the enzyme solution, and wipe off the excess on a paper towel.

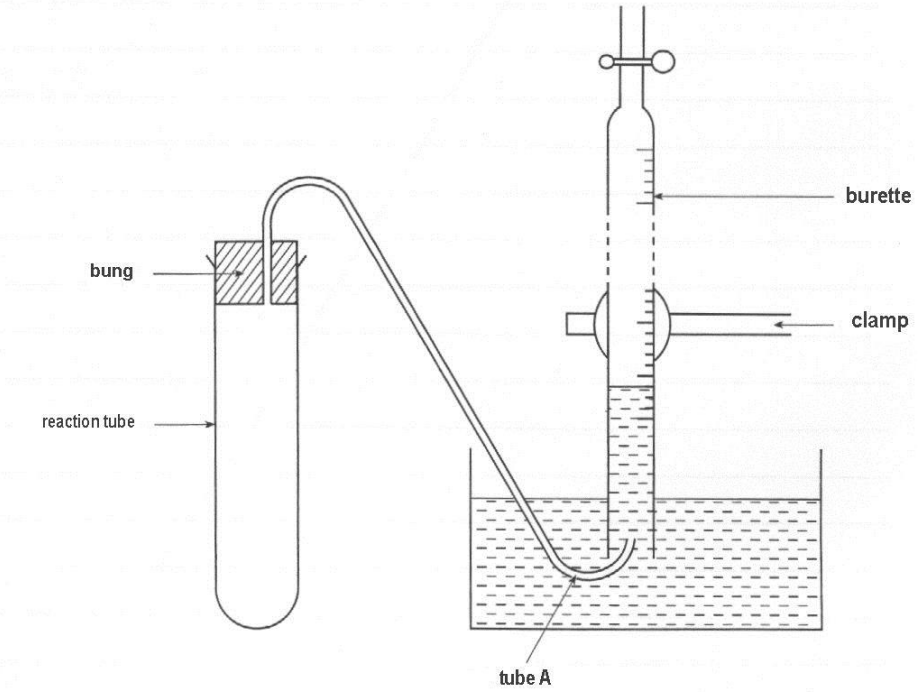
(3) Drop the filter paper disc into the 2% hydrogen peroxide solution and time how long it takes to float up to the surface.

(4) Remove the disk from the tube using forceps and discard.

(b) Catalase can be found in animal and plant tissue. It works by breaking down hydrogen peroxide, which is produced during biochemical reactions. The products of the breakdown are oxygen and water and the gas can be collected as follows.

Plan an investigation into factors affecting catalase activity and state the aim of your investigation. The following is a possible outline method.

Laboratory apparatus required to collect gas from a reaction tube,
Hydrogen peroxide (2%),
Measuring cylinders, syringes or pipettes,
Stop watch or clock,
3 red kidney beans, already soaked in water for 24 hours and crushed,
Buffer pH7



Set up the apparatus as shown in the diagram. (In order to fill the burette, clamp it in the normal way up with the tap / clip / narrow end at the bottom, fill it with water to approximately 10 cm from the top. Place a finger over the open end and turn the burette over. Now place the open end of the burette under the water in the container and remove your finger.)

(1) Record the initial burette reading (i.e. the position of the meniscus).

(2) Take the bung out of the reaction tube. Ensure that the tubing connected to the reaction tube (tube A in the diagram) is in the water, but not directly under the burette.

(3) Put hydrogen peroxide and 2 cm^3 of the buffer pH7 into the reaction tube.

(4) Add one of the crushed beans provided.

(5) Immediately you have done this, insert the bung in the reaction tube.

(6) After 30 seconds place tube A under the burette. You will observe bubbles of oxygen rising from the tube into the burette.

(7) Record the position of the meniscus in the burette at intervals.

(c) There are a number of factors which affect the rate at which an enzyme catalysed reaction takes place. It is possible to determine this rate in a variety of ways, including measuring the volume of gas produced during the reaction.

Plan an investigation into factors affecting enzyme activity and state the aim of your investigation. The following is a possible outline method.

Using the following:

Potatoes
Hydrogen peroxide solution,
Cork borer,
Phosphate buffer, pH 7
Burette
Glass tubing
Boiling tube
Rubber bung with hole
Water trough

(1) Place $10cm^3$ of 0.5M hydrogen peroxide solution into the boiling tube.

(2) Add to this $2cm^3$ of phosphate buffer, pH 7.

(3) Cut ten discs from a cylinder of potato cut using the cork borer. Ensure that the discs of potato are no more than 2mm thick and are of a consistent thickness.

(4) Place the ten discs of potato into the boiling tube. Shake the tube to ensure the separation of the discs.

(5) Connect the boiling tube to the burette

Leave for 20 seconds and then record the volume of oxygen produced in 3 minutes.

BY6 (d) The rate at which respiration occurs is temperature dependent.
It is possible to determine the rate of respiration by using the dye methylene blue which reacts in a very similar manner to that of certain chemicals in living cells.

methylene blue (blue colour)	⇌	reduced methylene blue (colourless)

Plan an investigation into factors affecting respiration and state the aim of your investigation. The following is a possible outline method.

Using the following:

Methylene Blue
Yeast Suspension
Water baths
Test tubes
Stop Clock

(1) Place $10cm^3$ of the yeast suspension into a test-tube.

(2) Place the test-tube of yeast suspension in a water bath for at least 10 minutes.

(3) After 10 minutes, add $1cm^3$ of methylene blue and shake gently.

(4) Leaving the test-tube in the water bath, and record your results.

(5) Keep your first tube as your colour reference for other reactions

(6) Calculate the time for the methylene blue to become colourless

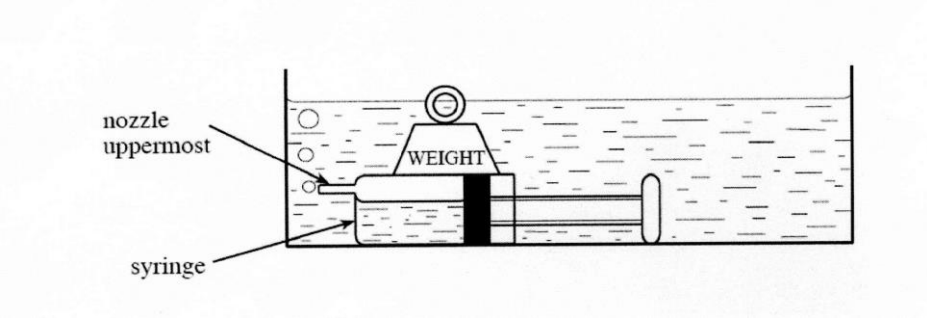
In all these investigations the candidate has to write the aim/prediction and decide which variables are dependent/independent. In addition, there is no reference to ranges or repeats given thereby allowing access to the relevant marking points.

(e) Yeast is unicellular organism, which respires producing carbon dioxide. Respiration is controlled by enzymes. The rate at which carbon dioxide is produced can be used to measure the rate of respiration of yeast. The following is a possible outline method.

yeast suspension (5%)
glucose solutiuon 0.2 mol md^{-3}
thermometer
thermostatic water bath
syringe
weight
Stirring rod
Stop watch

Method

1. Stir the yeast suspension, and draw $5cm^3$ into a syringe.
2. Was the outside of the syringe under a running tap.
3. Draw $10cm^3$ of glucose solution into the same syringe.
4. Pull the plunger back to almost the end of the barrel and shake the syringe gently.
5. Place the syringe into the water bath. The nozzle of the syringe is not central so when you lay the syringe down in the water ensure that the nozzle remains uppermost. Place a weight on the syringe to keep it in place. See diagram below.



6. After 10-15 minutes, bubbles of gas should be observed leaving the nozzles regularly. If the bubbles are appearing regularly start counting the number of bubbles that appear from the nozzle of the first syringe. Count the number of bubbles given off in 1 minutes.

Commonly submitted/reproducible investigations

This is not an exhaustive list nor is it intended to suggest that centres are limited to these investigations.

AS
Catalase experiments
Permeability of beetroot cells

A2
Methylene blue and respiration
Photosynthesis e.g. Algal balls (SAPS) or *Elodea*
Effect of antimicrobial agents e.g. penicillin/dettol on *M. luteus*

Appendix 2

AS BIOLOGY/HUMAN BIOLOGY
ASSESSMENT UNIT BY3 / BY6

B/H3 B/H6

COVER SHEET
PRACTICAL ASSESSMENT 20...

Centre Name: _____ **Centre Number:** _____

Candidate's Name (in full): _____ **Candidate Number:** _____

Title of Investigation: _____

_____

NOTICE TO CANDIDATE

The work you submit for assessment must be your own.

If you copy any work from someone else, allow another candidate to copy from you, or if you cheat in any other way, you may be disqualified from at least the subject concerned.

Declaration by Candidate:

I have read and understood the **Notice to Candidate** (above). I have produced the attached work under supervision in class and without assistance other than that which my teacher has explained is acceptable within the specification.

Candidate Signature: …….. **Date:** ……

Declaration by Teacher:

I confirm that the candidate's work was conducted under the conditions laid out by the specification. This includes no access to a mark scheme other than that contained within this booklet.

I have authenticated the candidate's work and am satisfied that to the best of my knowledge the work produced is solely that of the candidate. I confirm that the candidate's practical work was carried out with due regard to safety and with skill and care.

Teacher's Signature: …… **Date:** ……

Please indicate (√) that **one** piece of microscope work (with candidates name) is attached to this booklet.

_____

	Markers Only			
	BY3 Max. Mark	**BY3 Mark Awarded**	**BY6 Max.Mark**	**BY6 Mark Awarded**
Design	11		11	
Results	11		12	
Analysis	12		16	
Further Work	4		5	
Microscope	6		6	
TOTAL MARK	**44**		**50**	

APPENDIX 3

GENERAL CERTIFICATE OF EDUCATION
TYSTYSGRIF ADDYSG GYFFREDINOL

AS/A2 BIOLOGY/HUMAN BIOLOGY

B/HA

PRACTICAL ASSESSMENT 20...

ASSESSMENT UNIT 3/6

Centre Name: _____ **Centre Number:** _____

Please note below any points which should be brought to the examiner's attention.

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Teacher's Signature: …… **Date:** ……

APPENDIX 5

GENERAL CERTIFICATE OF EDUCATION
TYSTYSGRIF ADDYSG GYFFREDINOL

AS/A2 BIOLOGY/HUMAN BIOLOGY

PRACTICAL ASSESSMENT

Checklist for completing the report of an investigation

1. Aim/Prediction

2. Experimental Design

Details of Independent variable- range; units

Details of Dependent variable- units

Details of Controlled variables- values

Repeatability

Control experiment

Safety risk assessment

3. Results

Suitable table
(Headings; units; repeats; recording)

Graph or statistical test as appropriate
(Axis labels; units; grid use; scales; plots; line)

4. Analysis of results

Trend
Consistency
Sources of uncertainty plus improvement
Explain/relate results to theory
Conclusion

5. Plan for Further work

Further investigation with different independent variable
Controlled variables
Expected results